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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF

IRELAND.

SEVENTY-THIRD SESSION, NOV. 1907, TO MAY 1908.

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CONTENTS.

	PAGE
President's Address - - - - -	1
The Quebec Bridge Disaster. By W. E. LILLY, D.Sc., Member - - - - - -	27
Trinidad Lake Ashphalt. By M. W. FOLEY, Associate Member - - - - - -	46
Kildare and other Sewerage Works. By FRANCIS BERGIN, Member - - - - - -	71
Description of the Works in Connection with the Proposed Additional Storage Reservoir at Roundwood, Co. Wicklow, for the Corporation of Dublin. By JOHN G. O'SULLIVAN, Member - - - -	94
Annual General Meeting - - - - -	121
Ordinary General Meeting - - - -	122
The Protection of Engineering Structures from Lightning. By J. T. JACKSON, Member - - - -	122
General Meeting of Corporate Members - - -	149

Report of Council for 1907–1908, *Auditors' Reports and Statements of Accounts for* 1907.

List of Members for 1907.

TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

[6th November, 1907.]

MR. J. H. MOORE, President, in the Chair.

The following candidates were balloted for and duly elected:—

LAURENCE J. KETTLE, as a Member.
WILLIAM A. CHEEKE, as a Member.
JAMES H. MARR, as an Associate Member.

MR. J. H. MOORE, President, delivered his Address as follows:—

GENTLEMEN,—

I HAVE to tender you my sincere thanks for the high honour done to me in electing me as your President, and I trust that, with your support, the interests of the Institution will not suffer at my hands. When looking over the roll of Past-Presidents, whose names and portraits are now brought before us on our walls, it is difficult to avoid becoming a *laudator temporis acti*, and not to feel how unfit I am to occupy their chair. However, the Wise Man has said—"Say not thou that the former days were better than these, for thou dost not inquire wisely concerning this." To come, then, to the present, I have the pleasure of calling attention to the satisfactory state of

your finances and the small amount of arrears outstanding. The number of Members now on our roll is 156, of Associate Members 89, and of Associates 46, being nearly the same as last year, but showing a considerable increase on the numbers five years ago, in 1902, when the figures were 140, 33, and 61 respectively. The rule made by the Local Government Board that our Members and Associate Members were *ipso facto* qualified for sundry posts under the County and District Councils no doubt induced some to apply for enrolment who perhaps would not otherwise have done so. If all qualified engineers would join our ranks it would largely increase our influence and go far to prevent appointments being given to unqualified men, as occasionally happens.

The first difficulty which meets a President is the choice of a subject for an Address. I propose to give a brief sketch of the progress of Civil Engineering in Ireland and the prospects of employment for Civil Engineers at present.

The first thing that requires the services of the Civil Engineer in any country is the construction of roads. There can be no civilisation without means of communication.

Prior to the eighteenth century means of inland communication in Ireland, and even in England, were practically non-existent. There was nothing that deserved the name of roads, and few bridges.

In England there had been, of course, the Roman roads, and in Ireland there were from an early period some roads—such as the five roads leading from Tara, two of which, those going north and south, are still in existence, and used as county roads for a few miles, and can be traced somewhat further. The south road reached the Liffey at Stoney Batter, "the stoned road," and crossed

the river by the ford of hurdles which gave its name to *Baile atha cliath*, now Dublin, and went on by Booterstown (Road Town). This road (and most of the ancient roads) was paved with large stones, and many of these paved roads are still in use, and give no small trouble to the modern road-maker who tries to keep the pavement covered with broken stones or gravel. They run for the most part in straight lines, over hill and dale, preferring the tops of the hills. Part of the old road from Trim to Dublin, by Galtrim, is still in use and runs along the top of the Esker ridge. How these roads were made or maintained I am unable to say. As the Irish chieftains or kings were perpetually at war, anything like road maintenance, in our sense of the word, was impossible. We read that just before the Norman invasion the construction of a bridge at Athlone by the King of Connaught meant a declaration of war against the King of Meath.

The first King of England who treated the Irish as subjects, and not as enemies, was James I., and in the eleventh year of his reign—1613—an Act was passed at a Parliament held in Dublin (11 Jas. I., cap. 7) by which the duty of repairing the highways was thrown on the parishes in which the roads were situated. The churchwardens were to meet at Easter and fix a week—before St. John Baptist's Day—in which the roads were to be repaired—each occupier to contribute so many carts, horses, and men, the parish finding, if necessary, picks, shovels, and bars. This continued to be the sole means of repairing the roads for 150 years. Amending Acts were passed in 1710 and 1727, but the six-days' labour principle continued. As this arrangement proved quite inadequate for main roads, Acts were passed, commencing in 1729, handing over the principal roads to trustees, who were empowered to borrow money, build turn-pikes,

and levy tolls. The first road so dealt with was the road from Dublin to Kilcullen, the second Dublin to Navan; the roads to Dunleer and Kinnegad followed. The Acts limited the terms to twenty-one years, by which time it was expected that the roads would be in a proper state of repair, and the debts cleared off, but this never happened, and amending Acts were passed from time to time extending the period, until the final abolition of turnpikes in 1855. The first Acts simply authorised the repair, widening, and maintenance of existing roads, though subsequently new roads were made in the shape of diversions and extensions.

In the period from 1753 to 1767 the finances of the country seem to have been in a flourishing state, for there was an annual surplus of about £50,000 which Parliament voted away for public works—the total sum so voted amounting to £717,944. Most of this was expended on navigation, only £1,500 going for roads and £15,730 for bridges. This sum includes £9,130 for Kilkenny Bridge, an enormous sum, and expended to so little advantage that after obstructing the traffic for a century and a half, it is at length to be pulled down and rebuilt for about two-thirds of the original cost. No less than £26,716 was expended on building churches. This mode of disposing of the surplus came to an end for the double reason that there was too much jobbery connected with it, and that there ceased to be any surplus to dispose of.

The first Grand Jury Act was passed in 1763 (5 Geo. III., cap. 14), repealing the Six Days' Labour Acts and authorising the Grand Juries to pass presentments for repair and maintenance of roads and construction of new roads. This did not affect the turnpike roads, and power to enter into maintenance contracts was not granted till 1777, and then only for roads the rate on which was 3d.

per perch, subsequently extended to 6d. Applications for presentments under this and subsequent Acts were to be made "on the affidavit of two credible persons who could read and write," that the repairs or works proposed were necessary and for the public advantage. Section 24 recites that "the roads in this kingdom are very much annoyed and damaged by the narrow wheels of carts," &c., and enacts that the owner of a cart, the tires of which were less than three inches wide should be liable to a fine of 10s., to be paid to the person who should seize said cart, &c., and bring the offender before a magistrate. Double toll was to be levied on such vehicles, and remissions granted to those which had wider wheels. Why so salutary a provision was ever abandoned I cannot understand.

Under this system the by-roads improved, and Arthur Young, in his tour—1776-79—gives a glowing description of the good roads in Ireland. The passage has often been quoted, but with some omissions. He says:—"For a country so very far behind us as Ireland to have got suddenly so much the start of us in the article of roads is a spectacle that cannot fail to strike the English traveller exceedingly, but from this commendation the turnpikes in general must be excluded, for they are as bad as the by-roads are admirable. It is a common complaint that the tolls of the turnpikes are so many jobs, and the roads left in a state that would disgrace the kingdom." As to the by-roads he says that the resident gentry got presentments for the roads in their own neighbourhood. "For a few years the good roads were all found leading from houses like rays from a center, with an intervening space without any communication, but every year brought the remedy, till those rays met and communication was complete."

He then describes the mode of construction of these roads, by throwing up a foundation of earth in the middle of the space from the outsides. A layer of limestone, broken to the size of a turkey's egg, was spread on this, with a thin scattering of earth to bind the stones, and over that a coat of gravel. "Their carriages considered, no fault is to be found with this mode, for the road is beautiful and admirable." He explains that the road could carry the light one-horse carts in use in Ireland, but that an English wagon would cut them to pieces. Most of the roads which are now in existence over the greater part of Ireland have been made on this principle, and are quite incapable of standing heavy traffic, especially when that traffic is carried on narrow tires, two inches wide.

The Act of 1771, authorising the construction of the Grand Canal, recites that many of the high roads leading to the City of Dublin were almost impassable. An Act passed in 1795, amending the Act for the road from Dublin to Mullingar, recites that £15,000 had been raised in debentures, and "that the road was in a ruinous and impassable state, and will require a very large sum of money to be expended thereon in widening and putting same in repair," and that the tolls were insufficient to pay the interest and repair the road, and provides for a reduction of the interest and extension of the time.

By the Act of 1855 the turnpikes were abolished, and the roads handed over to the Grand Juries and made free to the public. The debenture holders were compensated, and a charge imposed on the baronies which, where not extinguished by purchase, is paid to this day.

The debenture holders on the roads from Dublin to Knocksedan, Slane, Drogheda, and Mullingar were paid in full; from Dublin to Dunleer they got 1s. in the

pound; from Kinnegad to Athlone 10s.; and from Dublin to Carlow nothing.

The Act of 1763 continued in force till 1836, when a new Grand Jury Act was passed and County Surveyors appointed, who were to see that the money voted was properly expended. Under this Act the roads steadily improved, while the cost of maintenance was reduced, and many new local roads were made. Had the coaches continued to run, no doubt the main roads would have been extended and improved, but the advent of railways did away with the through traffic on the coach roads, which became almost deserted, while increased traffic was thrown on the roads leading to the stations, which in most cases were ill adapted to bear it.

The Grand Jury Act was repealed by the Local Government Act of 1898, and the control of the roads transferred to District and County Councils. Under this Act the entire initiative of any work, whether for maintenance of an existing road or the construction of a new road, rests with the District Councils, the County Councils having only a veto. In most counties certain roads have been declared to be main roads, and half the cost is levied off the County-at-Large, but the District Councillors still control the expenditure. Several counties have adopted a declaration that no roads are main roads, so that the District Councils have complete control. Not only do they control the expenditure, but they dictate the specification, and cases have occurred where the surveyor has been compelled to use inferior local stones and forbidden to import better material from elsewhere. The District Councils are for the most part composed of men of narrow views, whose chief idea is to make every lane leading to a few houses a county road, or even to make new roads to accommodate half a dozen occupiers, and who are most unlikely to join with other

districts or counties to improve the main lines of communication. The conditions also of the purchase of land have become very onerous, the land having now to be bought in fee-simple, as for a railway; both owner and occupier have to be compensated, and large costs incurred for proving title and conveyancing. It seems to me that unless the main roads are taken up by Government, as in France, and the cost charged on the whole country, with assistance from the Imperial Exchequer, there is no prospect of any material extension or improvement. The increased use of motor vehicles on roads has brought the question to the front. As the roads have improved, improved vehicles are brought into use to travel at higher speeds or carry heavier loads, and these in turn cause a demand for further improvements in the road. The same thing exactly has happened with the railways. A demand has been made in England that £1,000,000 should be expended in improving, widening, and straightening the existing main roads. Something of the kind is required here. The use of steam-rollers to consolidate the materials is slowly but surely extending, but at first its introduction was looked on with grave suspicion by the District Councillors, who thought they were being taxed for the rich man's pleasure cars. It is, however, beginning to dawn upon them that they derive benefit themselves from the improved surface, and that the use of the rollers, so far from being an extravagance, is an economy, and that the system of spreading stones to be ground in by the traffic is wasteful and barbarous. I have no doubt that ere long it will be illegal to spread broken stones on a road unless there is a roller ready to roll them in. The same result may be arrived at by bringing actions against District Councils for damage done to vehicles or animals by loose patches of stones.

Although the Act abolishing turnpikes threw open the

roads to the public, and established the principle that "the King's highway" is free to all, and that from thenceforward the question as to whether a road would pay a dividend on the cost of its construction was not to be taken into consideration, still there is a survival of the system to our own days in the case of certain bridges on which tolls are still levied, and which are in the hands of private companies. A notable case which has recently been the subject of inquiry is that of the bridge over the Suir at Waterford—an ancient wooden structure quite unsuited to the requirements of the present day, and which it is proposed to reconstruct and throw open to the public. The bridge constitutes the sole means of communication between the City of Waterford and the five lines of railway now meeting on the north side of the river. It is on the direct road from Waterford to Kilkenny, and is the only bridge for twelve miles. When the question of compensating the owners came up, they showed that they had been making 12 per cent. for some years, and claimed a sum (over £90,000) which would secure them this income in perpetuity, although it was admitted that the bridge could not last for ever, and must be rebuilt sooner or later. In the end they were awarded about two-thirds of the amount claimed, and appealed against the award as insufficient, but unsuccessfully. The estimates for building a permanent bridge range between £20,000 and £40,000, according to the materials employed. Now that the question of compensation has been settled, plans will, no doubt, be decided on and the work got in hands.

Unfortunately in the early days of railways the lines which took the place of the highways were handed over to private companies, who, subject to certain restrictions, work them solely with a view to profit. That, however.

the railways were still considered as being public highways is evident from the provisions of the early Railway Clauses Act, enabling private individuals to place their own engines and carriages on the lines and arrange with the companies as to running. The authorised rates are made up of separate charges, for the use of engines, the use of carriages, and the use of the railway. Under this clause many collieries and merchants own their wagons, but I am not aware that any private individuals ever ran their own locomotives and passenger carriages. In fact it was soon seen to be impracticable. The result is that the public are entirely in the hands of the railway companies, and that even where grants of public money have been made the lines are the property of the companies. In Ireland we find the whole country mapped out into districts which, by the companies at least, are looked upon and treated as their private territories, and any extension by one company into another company's district is looked upon as an act of hostility. In this way we see a number of branch lines ending at unimportant villages, which can never prove remunerative. A railway or road that is not a thoroughfare is of little use. To give a couple of examples:—The Great Northern has a branch to Oldcastle. A short extension of some fifteen miles would reach the Midland at Crossdoney, but this would be an invasion of the Midland district. The Midland has a line to Kingscourt which should go on to Carrickmacross and Castleblayney, but this would be an invasion of the Great Northern district. The results are unsatisfactory alike to the public and to the shareholders. It appears from published returns that the total capital of the English railways is about £1,287,000,000, of which 5 per cent., or some £63,000,000, pays no dividend whatever. The case in Ireland is probably worse. The original shareholders

of the Dublin and Meath, after some twenty years' working, during which they get no dividend, received when the line was purchased one shilling in the pound. The shareholders of the Navan and Kingscourt did not even get that; when the debentures and preference shares were discharged there was nothing left for them at all. In fact a large proportion of the money invested in railways might, so far as the original investors are concerned, have been thrown into the sea. Under these circumstances it is not likely that more capital will be subscribed to complete or extend the existing railway system. To meet this difficulty a system of baronial guarantees was devised, by which the Grand Juries, and now the County Councils, can guarantee half the interest on the capital subscribed, the Treasury paying the other half, but this has been found to involve such serious risks and responsibilities, notably in the case of the Tralee and Dingle Light Railway, that it is practically hopeless to expect any County Council to guarantee any railway, and railway construction is practically at a standstill. Very few of the guaranteed lines pay more than their working expenses, and the guaranteeing bodies are bound to maintain and work them at all costs.

Several railways were of late years made in the West of Ireland with the aid of Government grants under Mr. Balfour. For example, the Galway and Clifden. But even when the financial difficulties have been overcome in this way other difficulties arise. A free grant of £25,000 was offered to the Leitrim County Council to extend the existing light railway to the Arigna coal mines, and the Council were disposed thankfully to accept the gift, but the Council chamber was invaded, and the Councillors terrified by a mob of men armed with sticks, who represented the interests of the carters from

the mines whose occupation would be gone, and the scheme had to be abandoned. I understand, however, that it is to be revived, and the line extended to Sligo—let us hope with more success. A similar scene occurred quite recently in the same neighbourhood, where the boardroom of a District Council was invaded by a mob of labourers and the Councillors terrorised into acceding to their demands for cottages.

In spite, however, of all drawbacks one large railway scheme has recently been started, and though still incomplete gives great promise of success. I refer to the Fishguard and Rosslare route to Waterford and Cork, carried out chiefly by the Great Western Railway of England. It certainly is cheering to find that the directors of this great company should have taken such a hopeful view of the prospects of this country as to spend such large sums in opening this route. The line is still incomplete, as traffic between Cork and Waterford has still to go round by Mallow, and the railways in Cork are not yet connected; but this will doubtless ere long be accomplished. A somewhat more ambitious scheme is proposed in the North of Ireland, which depends entirely on expected subsidies from the Home and Canadian Governments—namely, the proposal to run a railway from Belmullet in Blacksod Bay by Ballina to Collooney (a distance of about eighty miles), and thence to improve the existing line by Enniskillen and Clones to Belfast (130 miles), to make a railway round Belfast to connect the Great Northern and Northern Counties Railways (a connection which is greatly needed), and so to run trains through from Belmullet to Larne (about 235 miles in all), the trains to be run on to a ferry-boat at Larne, and carried to Stranraer, and thence, *via* Carlisle, to the manufacturing districts and London (about 370 miles).

A third rail would have to be laid down on the Irish lines to accommodate trains of English gauge, a deep-water pier constructed at Belmullet, and the harbours at Larne and Stranraer improved to suit the ferry-boats. A railway from Belmullet to Collooney, Enniskillen, and Belfast would doubtless be of great local advantage, but as no doubt a considerable portion of the traffic which now goes to Dublin would be diverted to Belfast, the Midland Great Western, and, to some extent also, the Great Southern and Western would suffer. It seems to me that in view of the great speed of modern steamships nothing is gained by transhipping mails and passengers at an Irish port and conveying them across Ireland. This was pointed out some time ago by Dr. Stoney, and since then the speed of steamships has enormously increased, while that of trains is practically stationary. The "Lusitania" could land mails in Holyhead in less time than it takes to first land them at Queenstown, involving two transhipments, then conveying them by rail to Dublin, with a third transhipment, and thence by steamer to Holyhead. In fact I see it reported that the experiment is actually to be tried. The proposal to carry trains across in a ferry certainly gets rid of two transhipments. A more formidable difficulty exists in the dangerous character of the Mayo coast and the comparative narrowness of the entrance to Blacksod Bay. However, I must assume that the promoters have taken all these matters into consideration.

As a Royal Commission is at present engaged in inquiring into the state of inland navigation in Ireland and the best means of utilising the canals, I need not detain you at any length by discussing them. The Irish Parliament made large grants in aid of inland navigation. One object brought prominently to the front was

to facilitate the conveyance of coal to Dublin, but for some reason or other, except at Coalisland in Tyrone, no canal ever reached a coalfield, nor for that matter has any railway. The most extraordinary blunders were made in the construction of the canals. One which seems inexplicable consists in the fact that no standard size was prescribed for the locks, so that the boats of one canal cannot travel on another, and even on the same canal the locks are not of uniform width or depth, and as the smallest lock determined the size of the boats, the extra money spent on the larger locks was wasted. Enormous sums have been expended on these canals and navigation which never paid, even from the first. The Grand Canal, it is true, pays a small dividend, but that is in part derived from rents, and not earned by the traffic. The late Mr. James M'Cann, Chairman of the Grand Canal Company, was of opinion that canals were the one thing wanted to promote the prosperity of Ireland, and proposed the extension of the canal from Drogheda to Navan, to Kells on one hand, and to Trim, Hill of Down, and Edenderry, to meet the Grand Canal on the other. These extensions were actually surveyed and work begun on them over one hundred years ago, and portions of the unfinished canal are yet to be seen between Navan and Trim, and between the Hill of Down and Kinnegad. Now that Mr. M'Cann is gone, no one seems to share his views or disposed to carry out his projects.

The history of the Boyne Canal is curious. Half of it, from Drogheda to Carrick Dexter, was owned and maintained by the Board of Works; the other half, from Carrick Dexter to Navan by a Board of Trustees. Carrick Dexter lock was defective and dangerous; each party wanted to get rid of their obligations and sell to the other. At last an arrangement was come to by which the canal

was put into repair by the Board of Works, and handed over to a company with a capital of £3,500. The canal is now working, and pays a small dividend on this capital, which is less than 2 per cent. of the original cost of the canal, which amounted to about £200,000, the rest of the money being absolutely lost.

One great objection to canals and navigations is that they are incompatible for the most part with drainage, which it is agreed is of paramount importance in the development of Ireland. To keep a river dammed and a country flooded—as in the case of the Lower Bann—for the benefit of non-existent traffic seems very indefensible. In fact, no one defends it, but nothing is done to remedy it.

Owing chiefly to the change in land tenure the Act of 1863, which enables proprietors of flooded lands to form drainage districts, has become inoperative. A Commission, of which two of your Past-Presidents were members, sat recently, and collected evidence, and has issued a report suggesting changes in the law which, if carried into effect, would enable drainage to be carried out with some prospect of success. One difficulty, however, exists, which seems to be common to all public works in Ireland—namely, that the cost invariably exceeds the estimate, and that when it comes to paying for the works the occupiers almost invariably complain that the improvement is not equal to the charge, or, in other words, that the drainage does not pay. The excess of the cost over the estimate is largely due to excessive claims for compensation, law costs, and delays in construction which cause the addition of considerable sums for interest during construction. In some cases districts have been relieved by grants of public money, but in most cases the proprietors had to bear the loss as best they could. According to the report of the last Commission, out of

£2,390,612 spent under the Act of 1842, £1,348,678, or considerably more than half, was written off as a dead loss, and defrayed by the State. On the Suck Drainage, out of some £200,000 expended, £67,000, or less than one-third of the total, was fixed as the value of the improvement, £50,000 was granted by the State, £13,000 was charged to the counties, and the balance, some £70,000, had to be borne by the proprietors. The Bann and the Barrow are the most urgent cases of rivers requiring drainage, and it is admitted that State aid is absolutely necessary, but it does not seem to be forthcoming. Grants-in-aid were, indeed, promised in 1888, as appears from the Drainage Commission Report, but they were inadequate, and, as a matter of fact, nothing has since been done. When we see the enormous losses incurred by private individuals in constructing roads, railways, and canals for the benefit of the public, surely it is not unreasonable to ask that the cost of works of admitted necessity, and which cannot pay from a financial point of view, should be borne by the State. The outlay would necessarily be spread over a number of years, and if, say, £50,000 was voted annually for twenty years in aid of arterial drainage, with proper safeguards against jobbery, all that is required would be accomplished without unduly burdening anyone, and the smaller districts could be dealt with by the proprietors interested on the lines suggested in the report. Should a workable Act be passed there are numerous districts requiring drainage which would afford occupation to engineers for many years to come. There is, besides, the maintaining of existing drainage districts which has been strangely neglected in many cases, and which should be made compulsory. The Wilkinstown drainage district in Meath was so completely forgotten that one of the proprietors employed an engineer (one of our members) to

prepare a scheme with a view to forming a district. It was then discovered that the work had been already done in 1850, and the Board of Works, on the application of the proprietors, had the channels cleared. Another district near Oldcastle was also cleaned up by the Board of Works after a similar period of neglect. The Red Bog district, near Dunshaughlin, was neglected from 1850 to 1899. It is now maintained annually. The Curraha district (1850) is still derelict. So that in one county alone four districts remained derelict for some fifty years. Five districts in the adjoining County of Kildare have been placed in charge of the County Council—one (the Blackwater) jointly with the Meath County Council. One of these (the Kildare) had become wholly derelict. I may fairly assume that this state of affairs is not confined to Meath and Kildare, but is more or less general throughout the country.

So little success has attended the efforts to improve the smaller harbours on the east coast that I do not think it likely that any more money will be spent on them. In fact, there is not traffic enough to warrant it even were there some prospect of success. I refer to such harbours as Balbriggan, Skerries, Howth, Bray, Greystones, and Wicklow. Recently a scheme was proposed to improve the entrance to the Boyne and the harbour at Drogheda, but it is a melancholy sight to see the empty quays, which I remember some fifty years ago were crowded with little coasting brigs and schooners, chiefly engaged in the coal trade. The improvement of Dublin Harbour, however, shows what can be done by well-directed efforts, persisted in over a long series of years. Two hundred years ago it seemed a vain attempt to construct a harbour amid the sandbanks that beset the mouths of the Liffey, Dodder, and Tolka. Now, however, we have a harbour in which

the "Great Eastern" lay alongside the quays, where large steamers can come in and go out independently of the tides. Such a harbour benefits not merely Dublin, but the whole country, and is a national asset. I have not seen any attempt to tot up the outlay which has been required to achieve this result, but I may safely say that if it were treated as capital, and the revenues of the port as dividends, it would not be a profitable concern for the shareholders. I am not even able to say how much of the expenditure was provided by grants of public money in the early stages of the work, but no such grants have been made of recent years, and the revenues of the port are applied, not to paying dividends, but, after providing for maintenance, to paying off loans for improvements.

This was the idea at the bottom of the Turnpike Acts—viz., that the receipts should be applied to maintenance and repayment of loans, but they (from whatever reason) never sufficed. It was even contemplated in the Railway Act of 1835, but with the proviso that only net receipts over ten per cent. should be so applied, and as the dividends on no railway have reached this limit the clause is inoperative. It is fortunate that harbours have been placed on a different footing, and that they are not burdened with a constantly increasing charge for capital expenditure, as are the railways.

We may assume that in the case of the larger harbours, where there is a surplus revenue available for improvements or interest on loans, that improvements will be made, but in the case of the smaller harbours there is no prospect of anything being done unless at the public expense. A few weeks ago Sir Thomas Esmonde, Chairman of the Wexford County Council, called a special meeting of the Council to consider a proposal to borrow £40,000 on the security of the rates to improve several minor

harbours in that county, but the proposal was negatived. Possibly if he had put forward a less ambitious scheme, or if there had been any prospect of an equivalent grant from the State, the proposal would have met with a more favourable reception.

Three years ago—in 1904—several of our members visited Belfast, and, among other works, inspected the large graving-dock then in process of construction. A short description of the dock was given by Dr. Cochrane in his Address in December of the same year. Shortly after portion of the dock, which is being constructed in a sandbank, collapsed, owing, I believe, to incautious pumping. This unfortunate mishap has so retarded the work that it is still unfinished. I saw, however, yesterday a statement in the Press that the works are approaching completion. I hope that some of the engineers connected with the work will, when all is over, give us a paper with a detailed account of the failure and its cause and the means used to remedy it. There is nothing so instructive as an account of a failure, but, naturally, as a rule, failures are not published.

The increasing size of ships is rendering all the older docks useless. The Custom House Docks in Dublin were built—the old dock at the same time as the Custom House, in 1771, and the other two docks in 1820, by Rennie, all at the expense of the Government—to facilitate the collection of Customs duties. Mr. Griffith, Engineer to the Port and Docks Board, has kindly furnished us with a copy of his report, made in 1903, to the Port and Docks Board, and his scheme for their reconstruction. Models of the present and proposed docks are to be seen in the Irish International Exhibition, and a copy of a letter written by the Secretary of the Ballast Board in 1845, stating that the docks had been constructed in 1820 at a cost of £588,000, but

that no provision had been made for an increase of depth in the river, and that then, after twenty-five years, the river had been deepened four feet below the sill of the docks, which were unable even then to accommodate the vessels using the port.

Some twenty years more elapsed, and in 1866, after much haggling on the part of the Treasury (who wanted £40,000) and the Ballast Board (who offered £30,000), the docks and warehouses were handed over to the Ballast Board for £33,000, being ten years' purchase of the rent of the warehouses—no value being put on the docks, which were transferred on the understanding that they would be made suitable for the trade of the port. The Dublin Port and Docks Board succeeded the Ballast Board in 1867, and decided that they must deepen the quays along the river before beginning the docks, and for the last forty years the work of reconstructing the quay walls and the construction of the Alexandra Basin has proceeded steadily, with the result that such large vessels now enter the port that the docks are quite useless, and as new warehouses have been constructed lower down near the vessels, the warehouses at the docks are being deserted too. Mr. Griffith's estimate for reconstructing the docks and the quay walls adjoining on both sides of the river is £521,000, and the question is—Where is the money to come from? The matter seems to me to be of national and not merely of local importance. According to Mr. Griffith's report a total sum of £700,000 was expended by Government on the construction of these docks, which for sixty years have been of little or no use to the port. Surely it would not be unreasonable to expect that some portion at least of the much smaller sum required to reconstruct them should be defrayed out of the public purse. I fear if the work has to wait till it can be done

out of the surplus revenues of the port another generation will have passed away before anything can be done.

It is just thirty-nine years since the Vartry water was brought to Dublin, and since then waterworks have been constructed in the larger towns and villages, but a considerable field for employment is still to be looked for in supplying the smaller towns and villages with waterworks and sewers. The Rural District Councils are expending sums, considerable in the aggregate, on sinking wells and erecting pumps throughout the country to supply the wants of the rural population, but wells and hand-pumps are obviously insufficient for towns or villages, and as the necessity for a pure water supply is universally admitted the Urban and Rural District Councils find it impossible to defer any longer to take steps to meet the want. One of the difficulties is to fix the area of charge; but there is this advantage in waterworks that they are, I may safely say, paying speculations, and that the charge for water supply is invariably less than the cost of hand-pumping and carriage of water from wells. In these schemes the mode of distribution is much the same in every case, but considerable diversity necessarily exists in the source of supply, which is sometimes derived from a river or well, the water having to be pumped into a service tank or else from a gathering ground with a gravitation supply.

In Meath the towns of Kells and Navan have had waterworks for some few years, the supply being pumped from the rivers into service reservoirs on adjacent hills. Waterworks for Trim are being constructed, the supply being derived from a spring and pumped into a tank, which is to be made of Hennebique reinforced concrete—the third tank which has been constructed of this material in Ireland. But Oldcastle and Athboy and other smaller

villages are still without water supply, and the same state of affairs exists generally throughout the country, and will continue for some time to give employment and afford opportunities of exhibiting engineering skill in selection of sources of supply and means of storage. But laying on a supply of water brings with it the absolute necessity for a system of sewers to carry off the waste, and sewers do not commend themselves to the popular mind in country districts. They are costly to construct, liable to get choked and out of order, and a serious difficulty always arises as to the disposal of the sewage. In fact, if the provisions of the Rivers Pollution Act were strictly enforced it would be practically impossible to construct any sewers at all. All systems of purifying sewage are costly, and all, when intrusted to the average caretaker for maintenance, unsatisfactory. A filter that has become clogged with dirt is worse than no filter at all, and I fully concur in the remarks made by Mr. Kaye Parry at the Sanitary Congress, that if the solids are removed in settling tanks the fluid effluent may safely be discharged into a running stream. It must be recollected that the sewage of villages, as a rule, contains no discharge from manufactories. It is largely diluted with rain-water, as separate sewers are out of the question, and the quantity compared with the volume of water in most rivers is quite inappreciable. For example, all the sewage of Navan could be discharged by a 12-inch pipe. As a matter of fact, there are four outfalls, three into the Blackwater and the main outfall into the Boyne, and the sewage has been discharged direct into the rivers for some twenty years without causing any nuisance. Shoals of little fish can be seen at the mouths of the sewers. I find, however, since writing this, that the Urban Council are threatened with an action unless they adopt some

means of purification. The whole sewage of Trim goes into the Boyne, and ten miles lower down the whole water supply of Navan is pumped from the same river. Before this water supply was provided for Navan a jug of pump water would go bad and become offensive in twenty-four hours, but water from the Boyne above Navan kept sweet in bottles for a month. The whole sewage of Kells goes into the Blackwater.

Recently it was proposed to construct a system of sewers in Athboy, but it fell through owing to the impossibility of complying with the requirements of the Local Government Board as to purification. A sewer was then made in the main street by the County Council, nominally to carry off surface water, but which intercepts and carries off the sewage which was the immediate cause of complaint, and discharges it direct into the Athboy river, without causing annoyance to anyone. The whole question of the disposal of the sewage of the smaller towns and villages and, I would add, of the workhouses throughout the country, is in a most unsatisfactory state, and it is certainly to be regretted that a law should be on the statute book which it seems to be impossible to comply with. The Rivers Pollution Act contains a saving clause that sewage is not to be discharged into a river till it has been freed from its polluting ingredients "by the best practicable and available means," which in most cases seem to be no means at all.

The Main Drainage Works in Dublin have undoubtedly removed the nuisance created in the Liffey above the new outfall works at the Pigeon House, and the sewage is there discharged into the river without further purification beyond precipitation of the solids and treatment with lime, but the settling tanks are very offensive, and I fear a fresh and serious nuisance will arise there which

will occasion trouble in the future. The Rathmines sewage is discharged direct into the river further down, road detritus being intercepted by catch-pits.

The sewage of Belfast is discharged into the Lough, and has had the effect of promoting the growth of a green seaweed on the sloblands which gives an offensive smell at low water. How this is to be remedied is not very apparent.

Cork is still without intercepting sewers, but I see that a scheme is in contemplation.

Another source of employment for our junior members, and which bids fair to last for some years, is in the supervision of the building of labourers' cottages. It can hardly be called architecture, especially since stereotyped plans have been issued, and it certainly is not engineering. Still, as the work is entrusted to the surveyors of the Urban and District Councils, many of whom are Associate Members of our Institution, I can hardly pass it by without some reference. The first of these cottages was built some twenty-five years ago, and the work has gone on pretty steadily at the rate of about 1,000 cottages a year, but it is now proposed to expend £4,500,000, which, with purchase of plots, &c., will suffice to build some 26,000 more, as fast as they can be built, 200 to 400 in a single union. The mere marking of the sites on the Ordnance maps runs into hundreds of pounds to the surveyors, and though the fees are cut to a minimum they will amount in the aggregate to large sums. It is obvious that there are not contractors nor tradesmen enough in the country to build all these houses in a couple of years. Unless the work is spread over several years the glut of work will inevitably give rise to considerable inconvenience and disappointment.

I should have wished to say something about the ex-

tension of electric tramways and the prospects of electric traction on railways. Electric traction has been successfully employed for comparatively short distances and light traffic, but I have no doubt myself that it will not stop at this, but will ultimately be used for long distances and heavy traffic. But as electric engineering was hardly thought of in my college days I must leave the matter to more competent hands. We number several electrical engineers among our members, and I trust that some of them will favour us with papers giving the result of their experience and the prospects of future extension and development.

In conclusion, I am disposed to take a hopeful view of the situation. When we remember the dreadful crisis through which the country passed in the first half of the last century—a rebellion, a tithe war, and a famine—and the steady progress which has been made during the past fifty years we may, I think, feel assured that this rate of progress will not only be maintained, but increased. Much has been done, but more remains to be done. The evil of jobbery, which affected public works so much in the past, has been, if not wholly prevented, at least minimised by the publicity which attends all the proceedings of the new boards and councils. Quarterly reports, half-yearly audits, and occasional sworn inquiries go far to prevent any member or official of the councils from straying from the path of rectitude. If they do, they are pretty certain to be exposed.

Of course the maintenance of law and order is a *sine qua non*, and we must only hope that such examples of mob law as I referred to as taking place in Roscommon and Leitrim will be rendered impossible. To carry out public works the first requisite is money, and to get money there must be credit, and credit is easily damaged by

such proceedings. So far, however, Irish credit is good, the arrears of instalments and interest on past loans being almost negligible.

I look forward with confidence to a prosperous session, and that with increasing numbers and increasing influence we shall maintain the high standard bequeathed to us by our predecessors.

On the motion of Mr. J. P. GRIFFITH, Past-President, seconded by Mr. WILLIAM ROSS, Past-President, a vote of thanks was unanimously passed to Mr. J. H. MOORE for his Address.

[4th December, 1907.]

Mr. J. H. Moore, President, in the Chair.

The following candidates were balloted for and duly elected:—

James T. Jackson, as a Member.
George H. Knowles, as a Member.
James Quigley, as an Associate Member.
John Smith, as an Associate Member.
Richard H. C. Hall, as an Associate Member.

The Quebec Bridge Disaster.

By W. E. Lilly, D.Sc., Member.

On the afternoon of Thursday, the 30th of August last, the greater portion of the great cantilever bridge over the river St. Lawrence, at Quebec, collapsed, carrying with it some eighty-five workmen, of whom seventy-five lost their lives. The death-roll has been exceeded in some previous bridge disasters, but in other respects the catastrophe at Quebec is unparalleled.

The bridge when finished was to have exceeded the span of the Forth Bridge by some 90 feet, and would have been the largest span in the world. Mr. Theodore Cooper was the consulting engineer, and is perhaps the leading bridge consultant in the United States of America, and associated with him were Mr. E. A. Hoare, Chief Engineer, and Mr. J. S. Deane, Chief Engineer of the Phœnix Bridge Company. The contractors, who were also the designers of the structure, were the Phœnix Bridge Company, of Phœnixville, probably the largest bridge-building firm in America. From these particulars it would

appear that the highest talent in America, together with all that forethought could assure in the way of modern plant and material, was available. Such being the case, it is a matter of concern to all engineers to ascertain the causes underlying its failure.

The bridge was intended to carry two railroad and two electric car tracks, a highway, and two side-walks across the River St. Lawrence, and is shown as it was two days before the disaster on Fig. 1, and on Fig. 2 after the catastrophe had taken place. It was situated eight miles west of Quebec, and was to have been 3,240 feet long, 415 feet extreme height above low water, with a centre clearance of 150 feet above high water, and notable for its 50,000,000 lb. centre channel span, 1,800 feet long. Steel alone renders possible the construction of structures of so great a magnitude.

The structure was of the pin-jointed, open connected type—a feature of American practice in which every endeavour is made to reduce the amount of work done at the bridge site to a minimum, everything possible being done in the permanent bridge works of the contractor. The system had peculiar advantages at Quebec owing to the Canadian winter being five months long, and the necessity of stopping all work on the bridge site during the winter months. Figs. 1 and 3 give a good general idea of the structure, the parabolic chords of the cantilever consisting of eye-bars, and the lower parabolic chords rectangular boxes having four webs connected together by a light bracing, and through which pass the pins for the main verticals. The main vertical compression members were of the open type, the sides being connected together by light open bracing, the other compression members forming the bracing of the trusses were also generally of this type. The trusses as designed were

of the single intersection type. This form of construction, as will be seen from Figs. 1 and 3, necessitated subsidiary bracing members for the long compression verticals.

Great advantages were claimed for the American system of construction in the matter of lightness; and in comparing the Forth and Quebec Bridges it was pointed out that the dead load in the case of the former was nine and a half times the live load, whilst the corresponding figure for the latter was four and one-third to one—an apparent economy of some 60 per cent. The claim that this difference was due to the adoption of the American system of construction is, however, not tenable, as in the Forth Bridge a very much higher factor of safety had been adopted. In that structure the steel used in the compression members was not in any case stressed to more than seven and a-half tons per square inch, inclusive of a wind load of 56 lbs. per square foot, reckoned on twice the vertical projection of the structure, whereas the maximum stresses in the Quebec Bridge was nearly fourteen tons, or a factor of safety of nearly one-half that of the Forth Bridge.

Mr. F. W. Skinner, the correspondent to "Engineering," writing from the scene of the disaster, said that it seemed impossible to attribute the failure to anything but bad design and proportions of the structure. The material after examination appeared to be first-class, and the stresses in the various members did not in any case exceed three-quarters of the estimated load. Every care had been taken in the erection, and only experienced men employed.

The following points were noticed after the collapse—that in the body of the members where the lattice-work connected together webs or channels that usually the

lattice work buckled or sheared off the rivets, and allowed the webs to buckle and wreck the member before it developed its full compression strength. Evidently if a portion of the same total weight of steel in the member had been distributed in diaphragms or full-length cover-plates, the ultimate strength and efficiency of the members would have been increased, as the complete rectangular cross-sections formed by the tie-plates were generally found whole. The west truss lower-chord (shown in Fig. 4) in panel 9 counting from the anchor pier, or second from the main pier, was 57 feet long, and inclined at an angle of about 45 degrees with the horizontal. It was proportioned for a maximum working load of 15,268,000 lbs., and had a sectional area of 735 square inches, and, like all the other lower-chord members in the anchor arm, was built with four webs, four and a-half feet deep, connected by flange cover-plates at the ends and by intermediate angle-bar latticing on both flanges, and was about six and a-half feet wide over all. After collapse this member was found in worse condition than any other lower-chord section visible, being bent to the shape of a letter S. The corresponding member in the opposite truss was reported to be almost as bad.

An analysis of the balanced stresses at the main pier, and the results of suddenly removing one of the reactions there, together with the longitudinal movement of the anchor-arm trusses in falling, and the fact that the top-chords as a whole remained unbroken are interpreted as strong, if not conclusive, evidence that the initial failure occurred in panel 9 of the lower-chord of the west truss of the anchor-arm. But so far there has been no evidence discovered in the wreck tending to indicate in any degree the cause of the failure of the member.

It is, however, very significant that two days before the

collapse it was reported to the chief engineer that the webs of west lower-chord No. 9 were buckled.

The author is of the opinion that the causes of the disaster as mentioned were correctly diagnosed. Failure in engineering structures usually takes place by the collapse of a compression member, and is seldom due to the breakdown of the tension members. Moreover, the calculation required for the design of the compression does not proceed with the same accuracy as in the case of the tension members, and their design proceeds upon lines which are often more or less empirical.

Various reasons have been advanced in the technical Press to account for the failure of the lower-chord members referred to, the weakness of the design in the adoption of the lateral bracing, the influence of size as affecting the strength of such members, the fact that Euler's formula for columns only takes into consideration E. Young's modulus of elasticity, and does not involve the strength of the material. These and other explanations have been put forward in a tentative way to account for the failure, and it is not to be wondered at if the engineer suspends his judgment amongst so many conflicting opinions.

In a previous paper which the author had the honour of reading before the Institution on "The Economic Design of Columns," it was shown that some remarkable wave phenomena occur in connection with the secondary flexure of columns, and that the bearing of this phenomena upon the failure of columns was important, and that the ordinary formulas used for the design of columns did not take into consideration secondary flexure. There seems to be but little doubt that the failure of the chord members in the Quebec Bridge was due to this cause, and that the effect of secondary flexure had been neglected in

their design. It is now proposed to bring forward some further experimental work bearing on this subject, and to point out in what way the design of the chord members was defective when considered from this point of view. Before doing so a short *résumé* of the proposed modified formula, together with the experiments on struts of circular section, will be given.

If a short hollow metal tube be tested under direct thrust in the testing-machine it will fail by secondary flexure, or wrinkling, and the tube breaks up into a series of waves. It is to be noted, however, that in every strut, even with small loads, the wave formation exists; but until the elastic limit is passed, the deformation is so small as to make its observation impossible. From a comparison of the results obtained from a large number of tests it was shown that as the tube gets larger in diameter and the thickness smaller, the load producing failure becomes smaller, and it is not until the length of the tube becomes less than the length of one wave that the load producing failure approaches the resistance to compression of the material. Hence the true strength to compression of the tube is the load which produces the wave formation. From the experiments, and also from the analysis, of these waves it was found that the wave-length varied as the square root of the area of the cross-section. This result leads to the following equation for the limiting load:—

$$f = \frac{F}{1 + k\frac{\rho}{t}} \quad . \quad . \quad . \quad (1)$$

where

f = the limiting load in pounds per square inch on a column of one wave length.

F = the strength to compression of the material in pounds per square inch.

k = a constant = $\frac{1}{8}$ for mild steel = $\frac{1}{10}$ for wrought iron.

ρ = the radius of gyration of the circular cross-section of the column about a diameter.

t = the thickness of the circular cross-section.

For circular sections, which approximate to a solid bar, the value $\left(\frac{\rho}{t} - 0.5\right)$ should be used for $\frac{\rho}{t}$; for the usual sections in practice the 0.5 is negligible.

The above formula with the constants as given applies to circular sections. Further experiments on square, triangular, and other symmetrical figures show that the form of the formula is correct, the coefficient k having a particular value for each figure, and the values so far obtained indicate that the value of k is always greater than for the circular sections. A great deal of experimental work yet remains to be done before precise values for the different figures can be given to this coefficient.

The foregoing experiments show that in estimating the strength of the strut it is not sufficient only to consider the length and the radius of gyration of the cross-section, but that some provision must be made to allow for secondary flexure. A means of doing this will now be considered.

The Rankine-Gordon formula for struts is:—

$$p = \frac{P}{A} = \frac{f}{1 + c\left(\frac{l}{\rho}\right)^2},$$

where

f = about two-thirds the compressive strength of the material; for wrought iron = 36,000 lb. per square inch.

A = area of the cross-section, in square inches.

$c = \frac{1}{9000}$ for struts with round ends.

$c = \frac{1}{36000}$ for struts with fixed ends.
l = length of strut, in inches.
ρ = radius of gyration, in inches.
P = total load on strut, in pounds.
p = load per square inch on struts, in pounds.

From the inspection of this formula it will be noted that the following conditions are supposed to hold true, that the strength of the strut is proportional to its sectional area, the other terms being supposed constant; also that any arbitrary value of ρ can be assumed, and therefore any ratio of ρ/t, without affecting the strength of the strut. It will be evident from the investigation on the effect of secondary flexure that these conditions do not hold true, and therefore the formula requires modification in this respect.

Now it can be shown from theory that the formula can be put in the following form:—

$$p = \frac{P}{A} = \frac{f}{1 + \frac{m f}{\pi^2 E}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad (2)$$

where E = Young's modulus of elasticity, and m a constant, the other terms having the same significations as already given.

Referring back now to equation (1), the value of f has been shown to depend on the deformation due to secondary flexure, and not upon the strength to compression of the material. The arbitrary constant f in the Rankine-Gordon formula thus becomes a variable, and, on substitution of the value obtained for f in equation (1), the following modified formula is obtained:—

$$p = \frac{P}{A} = \frac{F}{1 + k\frac{\rho}{t} + c\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad (3)$$

where $c = \frac{m F}{\pi^2 E}$. This formula takes into consideration

both primary and secondary flexure, and its solution involves the length and the figure and thickness of the cross-section of the strut. Also, by giving values to k pertaining to the different figures of the cross-section, it can be applied generally to all forms of struts.

To determine the proportions of the economic strut it is necessary to express the thickness t in terms of ρ and the area A of the cross-section. Now the area admits of being expressed in terms of its mean length and thickness. Thus, in the case of the circular cross-section, if $r =$ the mean radius, then $2\ \pi\ r\ t = \mathrm{A}$, also for thin sections $r = \sqrt{2}\,\rho$ nearly; hence, $\dfrac{\mathrm{A}}{2\,\pi\,\sqrt{2}\,\rho} = t$. On substitution of this value in equation (3), and differentiating with regard to p and ρ as variables, the condition obtained for a maximum is

$$\frac{\rho}{t}\,\frac{\rho^2}{l^2} = \frac{c}{k} \quad . \quad . \quad . \quad (4)$$

This result gives a rapid means of approximating to the proportions of the economic strut, and with different values of k applies to all forms of cross-section.

From a careful comparison of the published tests on solid columns, the best value to adopt for m is unity, giving $c = \dfrac{\mathrm{F}}{\pi^2\,\mathrm{E}}$; and if for mild steel, $\mathrm{F} = 80{,}000$ and $\mathrm{E} = 30{,}000{,}000$, the value obtained for c is $\frac{1}{4000}$ nearly; also from the experiments on secondary flexure, the deduced value of k for mild steel is $\frac{1}{8}$, and on substitution for the constants the modified formula for mild steel struts with rounds ends is

$$p = \frac{\mathrm{P}}{\mathrm{A}} = \frac{80{,}000}{1 + \frac{1}{8}\frac{\rho}{t} + \frac{1}{4000}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad (5)$$

Before proceeding to discuss the relative value of the

different forms of cross-section and the most economic proportions for struts, an example may be given of the use of the formula which will show the necessity of providing against the deformation due to secondary flexure.

Two circular struts, shown in Fig. 5, were cut from the same length of tubing, and were thus identical in every respect; one of these was cut along its length, and the other was left intact; the struts were then fitted with round ends and tested. The load producing failure on the cut tube was 25 per cent. less than that carried by the other.

Now if the load carried by these two struts had been calculated by the Rankine-Gordon formula, or any other of the usually known formulæ for struts, the values obtained in both cases for the load producing failure would have been the same—that is, the formulæ only take into consideration the length and the radius of gyration, and do not consider the way in which the figure or shape of the cross-section may be built up. From the inspection of the struts shown in Fig. 5 it will be seen that, owing to the secondary flexure, the manner of their failure is different, and the strengths of the two sections cannot be compared together as having equal strength.

The modified formula makes provision for this, and in comparing two such struts different values for k would be used, for the circular section k is $\frac{1}{8}$, and for the split circular section of value of k is about $\frac{1}{4}$. It follows then, in designing the cross-section of a strut, that the figure or shape and the thickness must be considered together.

In the modified formula it has been shown that for any particular figure there is some particular value of k, and when this is given, the economic proportions for the strut can immediately be determined. The question then arises as to what form the figure should take in order to

design the strut of maximum economy. Now F and c are constants in the formula, and it is the coefficient k which depends on the figure of the cross-section. If k then is kept as small as possible, the value of the load carried will be the greatest possible. So far as the investigation on different sections has gone, the value of k is least for the hollow circular sections; hence the circular sections give the strut of maximum economy.

The foregoing demonstration proves the necessity of allowing for the influence of secondary flexure on the figure of the cross-section in determining the strength of the strut. In order to do this, it is necessary that the values of the coefficient k for the different figures of cross-section should be determined. So far this has only been done for a few figures, and the values obtained have been derived from tests carried out on small specimens, for which reason they can only be looked upon as being approximate.

The different figures of the cross-section referred to are shown on Figs. 5A, 5B, and 5C, and may be considered in each case as being derived from the solid bar, the thickness of the cross-section is supposed to remain uniform as its figure gradually gets larger.

From the analysis the coefficient k is of the form $\frac{N\,F}{E}$, where N represents what may be called the tabular number of the figure. The numbers for each figure are shown on the left-hand side of the sections, and by multiplying these numbers by the strength to compression of the material divided by its modulus of elasticity, the value of k for that figure is immediately determined.

It will be noticed that in determining the constants c and k that the factor $\frac{F}{E}$ is common to both; hence it follows

that the economic proportions of the strut do not depend upon F or E.

The illustrations in Figs. 6 to 12 show the wave formation due to secondary flexure of the different sections in Figs. 5A, 5B, and 5C, and will prove of interest. As already remarked, wave formation of some kind exists in every strut, but within the elastic limits the smallness of the deformation makes its observation impossible.

The causes to which the failure of the Quebec Bridge may be attributed can now be discussed. Before doing so, however, it is advisable to consider the manner of failure of a strut in which the figure of the cross-section is a square, and in which two parallel sides are thick compared with the other two sides, as shown in Fig. 13. If a short length of this strut be taken and placed under a direct thrust, it will, owing to the secondary flexure, take up a wave formation similar to that shown in Fig. 14 and that of the specimen shown in Fig. 7; and if the sides are of equal thickness, the wave-length becomes a minimum for that particular cross-section.

Now suppose that one pair of the parallel sides becomes thin compared with the other two sides, then the wave-length increases, and in the limit when the sides disappear altogether, the two thick sides become two separate struts, as shown in Fig. 15. The strength, then, of a strut of this kind to resist secondary flexure is a maximum when the sides are of equal thickness, and the manner of its failure is somewhat as shown in Fig. 16. The wrinkling or crumpling up of the side of the strut introduces complications, and the laws of simple bending can no longer be said to hold true, more especially when the elastic limit is passed; also, the thinner one pair of sides becomes relatively to the other the more pronounced does this effect become. The weakness of the thin sides in bracing or

connecting together the thick sides, for the transmission of the bending and shear stresses, is evident.

Some interesting cases of the deformation due to secondary flexure in girder and struts are given in "Clark's Britannia and Conway Tubular Bridges," and the description of the classic experiments of Fairbairn, Hopkinson, and Stephenson in determining the best proportions of the various members of these structures are instructive and interesting.

Consider now the effect of applying a direct thrust to a short strut of a similar cross-section to that of the lower-chord member of the Quebec Bridge, as shown in Fig. 17. The deformation caused by the secondary flexure will take up a wave formation somewhat as shown in Fig. 18, with the result that severe stresses would be set up in the bracing.

The length of the wave depends upon the thickness of the sides compared with the mean thickness of the bracing in a similar manner to that of the square strut shown in Fig. 7. In the case under consideration the complete wave-length is nearly equal to the distance apart of two of the horizontal members of the bracing. The reason for this is that owing to the sides of the struts being built up of plates and riveted together, they are relatively flexible compared with a solid bar of the same total thickness. The sketches of the two struts shown in Figs. 19 and 20 will make this clear. In the built-up strut for small deformations the plates slide over one another, notwithstanding the rivets, and it cannot be assumed that the bending is the same as for the solid strut of Fig. 20.

If the wave-length had been greater than that given above, the buckling of the web and the failure of the bracing would have taken place simultaneously, and the collapse of the bridge would have taken place two days earlier. From the views that have been put forward in

the foregoing investigation the way in which the cord member failed was probably as follows:—Under the applied load the strut had a small deflection, and one side of it showed signs of buckling, somewhat as shown in an exaggerated manner in Fig. 21; under the increased loading the deflection increased, severe stresses being set up in the bracing, causing it to fail. The side of the struts then approached each other, and the collapse of the strut as a whole took place.

The failure is to be attributed to the bad disposition of the material in the cross-section of the strut. If the same material had been distributed in the form of a stiffened hollow square or a circle, it would have carried the calculated stress with safety, although the factor of safety would have been small. In the Forth Bridge the compression members are of hollow circular cross-section, and judged in the light of this investigation of maximum economy, their design is a fitting memorial to the intuition of the late Sir Benjamin Baker.

The published formulæ used in designing the compression members of the Quebec Bridge do not in any way take into consideration the figure of the cross-section of these members; and, moreover, the forms of the formulæ are open to criticism, not being based on the usually-accepted theory of flexure. The values obtained from their use would certainly not agree with those obtained from a large range of experiments; within the ordinary practical ratios of l/p from 40 to 80, the values obtained would be fairly approximate, but their use could not with safety be extended beyond these values.

The experimental work on which the views put forward in this paper have been based has been mostly carried out on small sections; this has, of necessity, been the case owing to the small size of the testing-machine in the

engineering laboratory of Trinity College, Dublin, and the want of a sufficient endowment for carrying on research work. The phenomena accompanying secondary flexure have a very great influence on the economic design of girders, beams, struts, and other engineering structures; and it is to be hoped that money will be found for carrying on research work in this direction.

Mr. J. P. Griffith (Past-President), in proposing a vote of thanks to the author, said the paper was a valuable one, for the subject was attracting the attention of engineers not only in America but over the whole of Europe. As engineers they approached failures of the kind with something like reverence and a certain amount of awe. Few of them had not had failures of one kind or another, but very few had experience of anything approaching this disaster. Those who had followed the life of Theodore Cooper and his work as an American engineer could not fail to sympathise very deeply with him in his old age at this culminating failure of what they might call his life-work. He did not wish to express any opinion as to the actual responsibility for the failure, but certainly Mr. Cooper's name was associated with the designs and the carrying out of the work. This had been accepted by the public as a guarantee that this great work might be faced with confidence. It was, therefore, with sincere regret that he thought of this disaster, and his sympathy went out to the old man who, when he was drawing so close to the end of his great professional career, should be faced with such a momentous occurrence. He confessed to considerable reluctance in discussing this paper of the author until they had the decision of the distinguished Commission which was investigating the disaster. They awaited their verdict with

intense interest. He listened to the paper with very great interest, and he agreed with the author on the lines he took with regard to weak character of struts where the webs are light in comparison with what they might call the flanges. They could not shut their eyes to the fact that these webs might have to act as flanges, and in this way might sometimes have to do the work for which they were not designed.

Those who had devoted attention to the question of struts knew how much in the dark they were about them still. They looked with reverence to such works as the Britannia Bridge. When that bridge was being built very little was known of struts, but the builders faced the problem. By experiments on a large scale, supported by theoretical consideration, they found out what was safe for the structure. If these methods had been adopted on the Quebec Bridge it might have been better.

The author had very graphically described the bridge, and also the result of his researches in reference to the accident, but he (Mr. Griffith) must confess that the figures exhibited by the author did not satisfy him as to the reason of the failure. Undoubtedly, if these stresses had been reached there would only have been a factor of safety of 2, and the stresses would have reached the elastic limit of the material. These stresses, however, included those due to live load and wind pressure, which did not exist at the time of the accident. He was not satisfied with the author's reasoning on that point. It appeared to him there might have been some movement in the main pier supporting the cantilever. He had not discovered any evidence to bear out this idea, but certainly a slight movement in the pier would cause very intensified stresses in parts of the structure.

He did not, however, like to take part in any critical discussion until they had before them the full report of

the very strong Commission that was at present investigating the disaster. He hoped the author, when the report was issued, would give them a digest of the views of the very eminent men who were connected with the inquiry.

He would like to thank the author for giving the Institution the result of his researches with reference to the flexure of tubular columns. When he was in the Engineering School of Trinity College forty years ago they had not the same advantages and opportunities that the present-day students had. They had no laboratory, nor had they an assistant professor like Doctor Lilly, who devoted himself so whole-heartedly to the interests of the students and the profession by carrying out such valuable experiments. The Institution was deeply indebted to the author for time after time bringing them the details of these experiments and researches.

Mr. J. H. Ryan, in seconding the vote of thanks, said the paper was a very exhaustive one, and gave a very good description of the probable cause of the disaster to the Quebec Bridge. He did not think it was necessary for him to speak at any great length on the subject, especially after the remarks of Mr. Griffith. He did not feel competent to express any opinion on the subject-matter of the paper at the present stage. He had been in the United States and had seen many structures of the pin type of construction described by the author. It was almost universal in that country, owing chiefly to the reason that the structures can be erected in a much more rapid manner than by the methods used for riveted structures. The author had explained the reasons why the American engineers adopted these methods. Of course, the climatic conditions had a great deal to do with it, and there was also the desire for rapidity with which Americans like to do everything. He agreed with Mr.

Griffith that the present-day students in the Engineering School of Trinity College had a much better opportunity of gaining knowledge in physical research than Mr. Griffith or he had when they were students together, and it is to be hoped that further funds will be forthcoming for the purpose, and so enable the author to pursue his useful experiments, of which we have had from time to time so many brilliant examples.

THE PRESIDENT (Mr. J. H. Moore) said he was sure they would all accord the author a very hearty vote of thanks, and he deserved it, for the valuable paper he had brought before them.

When he was at Trinity College they had not such opportunities of seeing the experiments which they were now able to carry out in the College. He remembered in his time at College their Professor, Dr. Downing, always impressed upon them the necessity of making their bridges "stronger than strong enough." They were taught that strength was the most essential feature.

They might calculate the strength of girders, &c., but they had also to take into consideration the question of workmanship. They had to make allowance for bad welding in the wrought iron work, or defective casting by the foundry men. They never knew what flaws might develop, and they must make allowance for bad workmanship.

It was always well to make bridges very strong with a good factor of safety. He had been taught 5 to 1 was the proper factor of safety, but nowadays it seems to be much less. They should always remember that a chain was no stronger than the weakest link.

The history of failures was always interesting, and there was nothing like failures for teaching them what to avoid.

DR. LILLY, in reply, thanked the members for their

hearty vote of thanks. He was anxious to make it clear that the usual way of considering struts was not all that could be desired. The figure of the cross-section should be considered; it was the root of all the trouble in the present design.

He quite appreciated Mr. Griffith's remarks about the report of the Commissioners on the disaster, and to a certain extent it was invidious to comment upon the design, but that was not his feeling altogether. It might be well if they could give the Commissioners some inkling of the causes of the failure, so that when they were considering the question they might have as much light on the subject as possible. He did not think any movement of the pier would have an effect upon the struts. It was claimed by the Americans that the pin-joints readily adjusted themselves to a new position, and if the claim did not hold good it simply meant that it was the fault of the design.

He quite agreed with Mr. Griffith that experiments were very necessary, and he hoped that in the near future they would have sufficient money to carry on more of this research work. They were very much handicapped for the want of funds to carry out these investigations. It was a most expensive proceeding. They could not expect practical engineers to take very great interest in experiments which were carried out on small sections.

Like the President he had a great admiration for the manner in which the experiments for the Britannia Bridge were conducted. In making some of their tests of the struts no doubt they had cases of the wave formation which he had described. But they were not able to make a sufficient number of experiments, and did not succeed in pointing out the precise manner in which the wave formation influenced the design.

[8th January, 1903.]

Mr. J. H. Moore, President, in the Chair.

The following candidate was balloted for and duly elected:—

William A. Farnham, as an Associate Member.

Trinidad Lake Asphalt.

By M. W. Foley, Assoc. Member.

Trinidad Lake Asphalt is the product of the "Pitch Lake" in Trinidad, one of the British West India Islands. (Fig. No. 1.)

Trinidad was taken from the Spaniards by Abercromby about one hundred and ten years ago, and the Pitch Lake has remained in the possession of the Crown ever since, but its resources had not been utilised until about forty years ago.

The Island of Trinidad lies off the north coast of South America. It is bounded on the north by the Caribbean Sea, on the south by a narrow channel into which flow the waters of the northern and most westerly mouths of the Orinoco, on the east by the Atlantic, and on the west by the Gulf of Paria, the south and west bodies of water separating it from the mainland of Venezuela.

While there are deposits of asphalt or pitch to be found practically all over the island, the deposits of most importance, from a commercial point of view, are those situated on La Brea Point, in the wards of La Brea and Guapo, in the county of St. Patrick, along the western shore.

These deposits are nearly thirty miles in a straight line from Port of Spain, the seat of the Government, the most important harbour and port of entrance, and lie on the northern shore of the south-western peninsula, the point upon which they are situated being apparently preserved from destruction by the sea, which is elsewhere wearing away the coast, by the bituminous deposits which exist along the shore, and even some distance from it, and which, from their toughness, resist the action of the waves better than the soft rocks of this region.

Of these deposits, which are classified into two—viz., "Lake Asphalt" and "Land Asphalt"—by far the largest amount of asphalt is found in the lake at La Brea Point, the surface of which was supposed, some twelve or thirteen years ago, to be about 130 feet over sea level, and to cover an area of 114 to 120 acres, and is situated at the highest part of the point. The "land" deposits are scattered between this point and the sea towards La Brea, and are partly covered by soil, grass, &c.

From the level of the lake surface the ground slopes upwards all around, so that, according to scientists, the asphalt deposit lies in the crater of a volcano which has filled up with pitch.

This celebrated lake has been, so to speak, one of the wonders of the world, and few travellers go to the island without paying it a visit. It is possible to walk or ride over the whole surface without danger, except in and near the centre, where the asphalt is liquid and its depth unfathomable. (Fig. No. 2.)

The asphalt in its crude state is excavated from the surface of the lake, filled into trucks which are carried along a light tramway on the inside edge of the lake, and after about two days it would be difficult to find traces of the excavated patches, as they become swollen or

filled up again with a fresh eruption from the volcano. (Fig. No. 3.)

About sixteen years ago a series of borings were made upon the lake, that at the centre being carried down to a depth of over 130 feet, entirely through the pitch, which, as far as the writer could ascertain, possessed the same qualities as that on the surface.

The carrying of this boring deeper became impossible from the moving of the pitch, which inclined the tube forming the lining to one foot in six, and the cylinder fell over in a very short space of time and became buried, and from that day to this not a trace of it has been found. Although an expensive and most difficult experiment, it clearly proved the enormous depth of the crater and the uniform quality of the asphalt.

After the freshly-excavated asphalt is conveyed to the pier head, which runs out nearly 2,000 feet into the sea, it is tipped into vessels which are in readiness to receive their cargoes on both sides of the pier, and then shipped to all parts of the world. The work has created a good deal of employment in connection with excavating and loading, the men so employed numbering between 400 and 600. In one single month 20,000 tons of asphalt were loaded.

It may be rightly asked what becomes of the enormous quantities of asphalt taken out of the Pitch Lake. The bulk of it is used in laying pavements, but it is also largely used in various other ways, such as in mastic floors, flat roofs, sidewalks, &c., and where cementing, waterproofing, and insulating of the best description is required. Architects specify it for damp courses, cellar and basement floors, and, as a rule, its general use is adopted around the areas of large public buildings, &c.

Engineers who are acquainted with its use recommend

it in bridge building both for waterproofing and for traffic, and also in culverts, tunnels, and subways.

Electricians find it the best, cheapest, and most effective insulator known. Sanitary engineers avail themselves of its antiseptic properties in a number of ways. It is elastic, and can be safely used in several ways where other cements do not succeed, and where allowance has to be made for contraction and expansion it has never been found to fail.

Trinidad lake asphalt in its crude or natural state is an extremely uniform mixture of gas, water, bitumen, organic matter, and fine mineral matter, and from the following table it can be seen that it contains a considerable percentage of foreign matter.

The constituents are in the following proportions:—

Water and gas - -	29	per cent.
Organic matter, not bitumen	7	do.
Mineral matter - -	25	do.
Bitumen - - -	39	do.
	100	

The material, as already stated, is of the greatest uniformity in its composition, as it has been found that specimens collected at intervals of 100 feet and a depth of one foot below the surface of the deposit, and to a depth of nearly 140 feet at the centre, all have the same composition.

This depth, which is some few feet below sea level, does not indicate how far deeper the asphalt may extend. The borings prove how enormous the deposit is, and the idea of the mound being a crater was further confirmed.

Notwithstanding all that has been done, it seems hard

to understand that there is at such a height over the sea a bowl-like chasm or depression over 2,300 feet across and at least 140 feet deep, reaching under the sea level, and filled with a uniform mass of pitch, which must amount to millions of tons.

The mineral matter in Trinidad lake asphalt is as much a fixed constituent of the material as the bitumen. It has apparently become intermingled with the bitumen under peculiar conditions in some underground passages where the bitumen originates and meets an environment that results in the production of the asphalt itself. Some of the mineral matter is so fine that it cannot be separated from a solution of melted or dried Trinidad asphalt even after months of standing and treatment.

The bitumen of Trinidad lake asphalt amounts to about 56 per cent. of refined material. It is of a black, pitch-like colour, all pure bitumen. This bitumen is characterised by the large percentage of sulphur which it contains and the presence of nitrogen.

Organic matter in Trinidad asphalt contains a certain amount of material not soluble in the usual solvents for bituminous substances, such as grass, twigs, branches and decayed roots of trees, &c. All these are removed in the refining process, and the bitumen, after undergoing this process, is called "dried asphalt," or epure, which, after being dealt with in the refining plant, is filled into barrels containing from 400 to 500 lbs.

Refined Trinidad asphalt, after being dried and agitated with steam, differs very slightly in composition from the crude material, or rather from this material after the removal without heating of the water which it contains. By subjecting it to a high temperature and to agitation with steam, certain changes in its character occur.

General analysis of dried Trinidad lake asphalt:—

Bitumen, soluble -	57.00	per cent.
Mineral matter - -	36.50	do.
Organic matter, not soluble	6.50	do.
	100.00	

Mesh Composition:—

Passing through	200	meshes to square inch	85.40	per cent.
Do.	100	do.	9.10	do.
Do.	80	do.	5.50	do.
			100.00	

Trinidad Land Asphalt.—In the year 1892 Mr. Clifford Richardson described La Brea Point as consisting of a mass of hardened pitch deposits extending some distance into the gulf and along the shore in both directions.

The deposits are found in greater or less abundance at all points between the shore and the lake, and directly parallel with the road, over an area of about 1,000 acres. These deposits are, as already stated, covered at a distance from the lake, but as the lake is approached the covering becomes lighter until one comes to the naked asphalt. The deposits nearest the lake are softer and purer. It has been claimed that land asphalt is an overflow from volcanic eruptions in the lake. It differs considerably from lake asphalt in consequence of the changes which have taken place by its being covered over with soil, climatic circumstances, time, and the forest fires which have often swept over it. Both materials are evidently derived from the same source. It is also supposed that land asphalt may have reached its position either by an overflow from the lake or by its intrusion into the soil directly from the point of origin. In every case land asphalt has been found to vary according to its environment, so that it differs essentially from the lake material.

The land and lake deposits differ very much in colour, composition, &c. The lake asphalt has, with naphtha used as a solvent, 65.3 per cent. of its bitumen soluble, while just outside the lake it has only 61.1 per cent., and further on only 59.7 per cent. soluble. The difference may appear small, but it goes to prove a large change. In themselves they would not amount to a great deal unless confirmed by actual results found in the industrial use of the material. In fact, such confirmation is not lacking if "land" is used in the same way as "lake" asphalt—*i.e.*, if fluxed as an asphalt cement with a suitable residue of petroleum.

In the preparation of such an asphalt cement the most remarkable difference between lake and land asphalt is proved by the facts that where 20 pounds of a good paraffin petroleum residuum is sufficient to make a suitable asphalt cement, when added to each 100 pounds of lake asphalt, as much as 30 to 35 pounds of the same residuum are required to make a cement of the same consistency with land asphalt.

Experience in the use of both lake and land asphalts in the pavements of thoroughfares or roadways has shown that after a very short interval the wearing surfaces laid with land asphalt begin to show signs of deterioration. Practical results confirm those found by laboratory tests more clearly than may be imagined.

Trinidad Lake Asphalt Cement.—Whatever solid bitumen and fluxing or cementing oils are selected for this purpose, their careful combination is necessary for the preparation of a satisfactory asphalt cement. The dried asphalt already described is elevated to a platform in the works, carefully weighed, broken up, and lowered into large melting tanks, which are so constructed that no portion of their contents shall become readily over-heated.

The bottom should be protected from direct flame by a firebrick arch. Agitation is very necessary, not only for keeping the mineral matter in suspension, but to keep the material from too long contact with the sides of the tank, and of even temperature. Agitation with steam is undoubtedly the best method, as the action of air on all oils at a high temperature is very strong—the result of blowing an asphaltic residuum to a temperature of 350 degrees F. with air for twenty-four hours being to convert it into a semi-solid, buttery mass.

The melting tanks are capable of containing 20 to 22 barrels of dried asphalt (approximately 9,000 pounds) in addition to the petroleum residuum, which is added at the rate of 18 to 20 pounds of petroleum residuum to every 100 pounds of dried asphalt, or thereabouts, according to the requirements for the production of a cement for a specific purpose. This mixture of asphalt and residuum of petroleum, when melted, is raised to a temperature of from 150 to 200 degrees F., and if prepared for a paving mixture is raised to 290 degrees in warm weather and 310 degrees in cold.

It is very necessary in order to intermix the fluxing material with the asphalt that perforated steam coils should be used where possible. The steam should be at high pressure, and should not be admitted to the melted asphalt until the latter is at such temperature as to prevent condensation. Every precaution should be taken to keep the steam dry by blowing the water out of the pipes conveying it. The agitation should be kept up for such time as to ensure a thorough mixing of both substances. This process must be continued for four or five hours at least under the most favourable conditions. An experienced foreman can always tell by dipping a barrel stave into the tank or some other simple method, such as throw-

ing a small quantity of it into cold water, whether this admixture is fairly complete.

The asphalt cement having been found to be fairly agitated and properly mixed, the next step necessary is to determine whether it is up to the mark or consistency desired. This can also be judged by an experienced workman in various ways. The preliminary and most usual practical test is that of chewing a particle of the asphalt cement after cooling. A small sample is put into the mouth and worked between the teeth as it assumes the normal temperature of the body, and from previous experience in this way one can come to a reasonable conclusion.

There are, of course, many other ways of determining the consistency of asphalt cement, such as a flow test, which consists of comparing the relative flow, at temperatures above the softening point of the cement, of the sample about to be tested with that of a standard sample.

The best and most desirable way in the writer's experience of testing the consistency of asphalt cement is in the laboratory, with the Bowen penetration machine, for the reason that it admits of an absolute record of figures.

The description of the construction of the Bowen penetration machine, which the writer used in testing samples, is as follows (Figs. Nos. 4 and 5):—

"The machine is designed to register on a dial in degrees the depth to which a steel needle .027 of an inch in diameter, ground to a fine point, and attached to a lever, penetrates into the sample to be tested when allowed to act upon it for a second at a temperature of 78 degrees F.

Directions for using the penetrating machine, &c.:—

Setting up the Machine.—Remove the wooden block

upon which samples are placed, and release the clamps holding the base of the machine and the needle arm by turning them, but the screws should not be removed.

The machine should then be lifted out of the case and placed on a level table or stand and fastened with screws. Place the hand upon the spindle, and the pendulum on the rod, and the machine is ready for use.

When the machine is properly fixed and found to work satisfactorily in every way, the pendulum, suspended from a single thread, should be compared with a clock, and the beat can be regulated by means of a screw.

The sample to be tested should be placed in a specially made tin box, and should present a smooth surface freshly melted, as exposure to air hardens the exterior and interferes with the test.

An immersion of half an hour in water at from 78 to 80 degrees F. will suffice to bring the sample already described to a proper condition, and it must be remembered that the laboratory should be of the same temperature.

Two thermometers are necessary for penetration purposes—one to hang in the room to show its temperature, and the other should be placed in the water with the sample or samples as the case may be. A wooden tub is generally used for holding the warm water.

When it has been ascertained that the needle is properly fixed and pointed, &c., it is raised very much over the base, the wooden block is brought under it, and the sample carefully placed on three screws on the surface which supports the sample tin and prevents it from shifting.

A small round mirror is attached to the machine, which borrows light from the side window and causes a reflec-

tion on the surface of the sample about to be tested, and with the eye at an angle which experience will teach the needle is brought closely down to it.

A reading on the face of the dial is taken where the hand (similar to the minute hand of a clock) is resting.

Then the thumb of the right hand is placed on the knob or button which releases the thread; beat time with the right elbow to the motion of the pendulum, until a pressure of the thumb may be made in unison with it. The needle is then released, and the reading where the hand rests on the dial is taken, and by subtracting the former from the latter the penetration degree is arrived at. Practice and experience makes this test very easy and accurate.

The writer, from long experience, could estimate very nearly the penetration point by pressing the sample with the finger tip after being immediately taken out of the water of proper temperature, or by lifting a sharply-pointed lead pencil to a certain height and allow it drop into the sample.

Rules for penetration of asphalt cement:—

(1.) 1 lb. dried asphalt per 100 lbs. asphalt cement reduces the penetration by 4 degrees.

(2.) 1 lb. petroleum residuum per 300 lbs. asphalt cement raises the penetration by 4 degrees.

(3.) $\frac{1}{2}$ lb. petroleum residuum per 100 lbs. dried asphalt raises the penetration by 5 degrees.

The penetration of asphalt cement for "binder course," which will be dealt with later on, should be from 96 to 104 degrees, and that for wearing surface mixture from 69 to 73 degrees.

Formation of Trinidad Asphalt Pavements.—The Macadam roadway, or existing pavement, should be ex-

cavated and removed to such place as the borough or town surveyor, as the case may be, should direct, and a 6-inch thick layer of 6 to 1 concrete of Thames or other ballast (gravel) and approved Portland cement should be laid and properly formed to suit gradients, direction, width of thoroughfare, &c., as a base for the asphalt pavements. After the concrete base is sufficiently set the first or "binder course" is laid. Its composition is as follows:—Binder measure box contains, say, nine cubic feet of materials, or in weight 370 lbs. granite chips, 370 lbs. crushed flints; total 740 lbs.—50 lbs. asphalt cement, penetration 104 degrees. (Fig. No. 6.)

Sand screenings may also be used, but should be thoroughly free from dust, &c., and coal tar could be used as a substitute for asphalt cement on streets of light traffic with advantage regarding cost.

The amount of asphalt cement necessary to coat clean stone, free from grit and dust, will vary with the character of the stone and the nature of the asphalt cement.

The exact quantity can only be ascertained by experience. It should not be sufficient to run off the hot stone or too little to give a bright, glossy coating.

An excess may prove very injurious, as it collects at the bottom of the carts in quantities according to the air temperatures and the distance over which it is hauled from the works.

On the other hand, a slight excess may turn out beneficial on streets of very light traffic, where the finished surface would be liable to crack. It has been found in such cases that the surface is preserved where the excess is drawn up by the summer heat.

The consistency of asphalt cement used in "binder course" should be much softer than that in the wearing

surface, for various reasons. Experience and practice have clearly proved that the binder asphalt cement should be about 30 degrees penetration higher than that in surface mixtures.

The temperature of "binder" when ready to lay on the street should be no greater than is necessary to spread it out. It should be laid to at least a thickness of two inches to ensure a proper bond. It is spread with heated shovels, and evenly distributed with hot rakes, and allowed to get fairly cool before being steam-rolled.

Immediately after being rolled it is quite ready for the wearing surface, and it should be kept free from refuse, and perfectly dry.

The Surface Course.—The mixture which forms the surface should arrive upon the street at a temperature which cannot be defined in degrees of the thermometer. It should be hot enough to work freely under the rake if it has a properly balanced mineral aggregate, but in no case should it reach the temperature which the asphalt cement cannot resist without becoming too much hardened in the mixer, when being violently agitated with hot sand in contact with air.

A measuring box full of materials to make surface mixture was weighed in September, 1898, in London in the writer's presence, and the result was as follows:—

Weight of measuring box only -	162 lbs.
Weight of mineral aggregate -	869 lbs.
Total - - -	1,031 lbs.

The weight of a box of surface mixture laid in Pelham Street, Kensington, in 1897, resulted as follows:—

Trinidad asphalt cement, 142 lbs. (penetration 71 to 72 degrees); dust of filler, 141 lbs.; sand, 589 lbs., half white and half yellow. Total 872 lbs.

Analysis:—

Bitumen			11.10	per cent.
Passing 200 meshes to the sq. in.			17.90	do.
Do.	100	do.	11.90	do.
Do.	80	do.	20.30	do.
Do.	50	do.	33.80	do.
Do.	40	do.	2.70	do.
Do.	30	do.	1.50	do.
Do.	20	do.	.60	do.
Do.	10	do.	.20	do.
			100.00	

The sand in the mixture, as can be seen from its mesh composition, was very fine, and contained no large grit, so that it was considered to be most suitable for the purpose. Before being mixed with the other substances forming the surface it had to pass through a hot revolving cylinder, or drum, heated to from 300 to 380 degrees F., and conveyed by elevators to the measuring box, and from there to the mixer, where, with the other component parts, it is thoroughly prepared and then shot into the van or cart which is ready to receive it. The temperature is then taken and recorded, and the cart, before starting to the street, is carefully covered with a special tarpaulin. The temperature is again tested by the street foreman, and recorded as before, and in cases where a considerable loss of temperature occurred which rendered it too low for use in the street, the material had to be returned to the works, and stored for the purpose of being re-heated later on and used for repairing trenches made by gas, water, and other companies.

The surface mixture, when unloaded on the street, is moved with hot shovels from the point where it has been dumped to the place where it is to be raked out to the proper thickness for compression. This operation should

not be done too quickly. No more should be spread than the rakers can handle. The raking of the material to a proper grade requires the greatest skill and attention on the part of the rakers, foremen, &c.

The hot mixture, after being properly spread, raked, graded, &c., is allowed to cool to a degree at which it will not be displaced or picked up by the roller. To overcome this trouble a light hand-roller is used to give the first impression, after which the surface is sprinkled with a light coat of Portland cement, which gives it a nice dark brown colour. The excess of this dust being swept off, the surface is allowed to get much cooler, and finally the heavy (10 tons as a rule) steam-roller comes on to shape it properly without displacing or breaking any of the surface.

The appearance of the finished pavement, especially after it has been subjected to traffic, will depend as much on the the way it has been rolled as upon the way the mixture had been raked out.

The management of the steam-roller should only be placed in skilled and trustworthy hands. If not run with the greatest care and regularity, both in the longitudinal and diagonal rolling, the surface becomes so uneven that it would not be easy to bring it back into proper form. Directly after being rolled the channels are painted with a solution of asphalt, and smoothed over with hot smoothing irons, which are also used for smoothing down irregularities in places where the roller cannot reach—around gully-traps, &c.

The writer's first experience of this class of pavement was in the year 1894, when it was first introduced into London.

Works were erected at Fulham, and paving contracts obtained from the Vestries of South Kensington and Chelsea. In the autumn of that year Pelham Street, Kensington, and King's Road, Chelsea, were laid.

Pelham Street, from South Kensington District Railway Station, by Pelham Crescent to Fulham Road, and King's Road, in sections, intermingled with French Rock asphalt, between the World's End and Stanley Bridge.

After completion it was generally admitted that horses secured a better foothold on this than that of any other asphalt.

This pavement, however, soon showed signs of scaling and breaking up in many places, with the result that it went so badly during the winter of 1894-5 that it had to be relaid early the following spring. The following is a comparative analysis of Trinidad paving mixtures laid in London from the year 1894 to 1897 in the above streets:—

(1.) King's Road, 1894, Gunter's Grove Section, scaled, and had to be relaid.

(2.) King's Road, 1896, World's End Section, wearing satisfactorily.

(3.) King's Road, 1896, Stanley Bridge Section, wearing satisfactorily.

(4.) Pelham Street, 1897, the whole street, wearing satisfactorily.

	(1)	(2)	(3)	(4)
Bitumen -	9.70	10.20	11.00	11.40
Mesh Composition:—				
Passing 200 -	12.10	16.60	16.50	18.90
,, 100 -	8.20	12.10	14.00	13.70
,, 80 -	11.60	21.00	21.30	20.60
,, 50 -	31.90	25.10	31.00	31.20
,, 40 -	8.50	6.60	3.10	2.50
,, 30 -	11.20	4.80	1.70	1.20
,, 20 -	4.80	2.50	1.00	.50
,, 10 -	2.00	1.10	.40	0.00
	100.00	100.00	100.00	100.00

No. 4 mixture turned out so satisfactory that contracts were obtained in several parts of London, including Fulham, St. James's, &c., &c. The writer is informed that the period of guarantee has only expired in King's Road in the present year, and is now under maintenance contract for a further period. The same applies in the case of Pelham Street, so that it appears the pavements are still giving satisfaction after so many years' wear.

The Merits of Asphalt Pavements.—Whether an asphalt pavement possesses any lasting degree of merit will depend entirely upon the manner in which it is constructed from the base up, including proper drainage and the character of the surface mixture. It has already been made clear that the greatest care is necessary in all these respects.

It will be only worth while, therefore, to consider what are the merits of an asphalt pavement properly constructed:—

1. It can be brought, as it were, to the fine point of a needle, so as to meet all climatic conditions—heat, cold, frost, and moisture—and will not disintegrate under traffic, no matter how heavy.

2. Being impervious to moisture, it can be kept perfectly clean at very little cost, and does not absorb filthy liquids, as in the case of wood blocks.

3. Horses get a secure foothold, and can haul heavier loads over it with less force than upon any other pavement, and at the same time they are less liable to fall.

The writer has taken records of traffic on the busiest streets in London, over all classes of pavements, under different headings, such as slips, falls on haunches, complete falls, &c., with results that clearly prove that horses are more liable to severe falls on other pavements than those of asphalt.

4. Its wearing properties compare more than favourably with granite, and exceeds that of other pavements under heavy traffic.

5. *The Simple methods of making repairs.*—Cuts in the surface for underground work can be repaired in a manner which makes them undistinguishable from the original surface, whereas they are quite noticeable in the case of other pavements.

Cost of Asphalt Pavements.—The defects which have generally been assigned to an asphalt pavement are its comparatively great first cost and cost of maintenance. Its first cost may be larger than that of some other inferior forms of pavement, but if the cost is distributed over the length of time that an asphalt roadway will wear, it works out smaller per annum and per ton of traffic carried than that of any other form.

No accurate figures and no general statement can be made in regard to the cost of an asphalt pavement, as it varies according to many circumstances, some of which are as follow:—

1. The cost of transportation of the materials necessary for the erection of the plant in the locality where the pavement is to be laid.

2. Cost of materials in the composition of pavement—such as sand, cement, broken stone, and fine material used as filler.

3. Cost of local labour.

4. The form of construction specified by public bodies, &c.

5. The character of the traffic which the street is to carry—its grade, and the nature of pavements adjoining it.

6. The period of guarantee and the terms of payment.

The cost of maintenance is quite as uncertain as that of construction, and even more so.

Appended is copy of an abstract made out by the writer, showing cost of maintenance in London for the year 1898. From this it will be seen that the cost of repairing cuts is far in excess of the ordinary maintenance repairs. This is accounted for by the fact that reinstating concrete and "binder" is included in the former.

THE TRINIDAD LAKE ASPHALT PAVING COMPANY, LTD.

Summary of Reinstating Asphalt in Trenches, and General Maintenance of Roadways for the Year ending 31st December, 1898.

Name of Street	Reinstating Asphalt in Trenches									General Maintenance					
	Measurement super. yds.	Certificate £	s.	d.	Cost £	s.	d.	Cost per super. yd. s.	d.	Measurement super. yds.	Cost £	s.	d.	Cost per super. yd. s.	d.
James St.	3	2	9	6	2	16	11½	18	11¾	—	—			—	
* King's Rd.	10	8	5	0	6	10	2	13	0	63	21	9	1½	6	9½
† Pelham St.	9	6	6	9	5	13	3½	12	7	20	7	7	0	7	4½
Savile Row	—		—			—			—	—		—		—	
‡ Star Rd.	20	14	18	0	10	5	10	10	3½	2	1	5	1	12	6½
Totals	42	31	19	3	25	6	3	12	0	85	30	1	2½	7	

* From the 28th April to 31st December.
† From the 21st March to 31st December.
‡ From the 22nd March to 31st December.

The larger the area of maintenance the cheaper the cost, as in the case of small patching the carting of tools, &c., to and fro entails as much expense as if a large amount of repairing had to be done.

In conclusion, it may be well to state that during the years the writer had been connected with the asphalt in-

dustry he had every opportunity of becoming acquainted with every department of the business, both at the works and on the streets, and kept a diary (which is carefully preserved) of everything he saw in connection with the treatment, testing, &c., of anything that came into the laboratory, as well as the general handling of materials at works and streets, making daily returns of work done on specially-prepared diagrams, and at the completion of each contract made a detailed abstract showing the cost of each class of work separately.

A monthly bulletin on the progress of Trinidad asphalt in the United States of America was regularly received by the writer, and from these he also collected information, as well as from the writings of Professor Clifford Richardson, of Long Island City, who, it appears, is the greatest living authority on asphalt generally. Mr. Richardson, who was one of the first in connection with starting Trinidad asphalt pavements in London, is well known to the writer.

Mr. G. M. Ross, in proposing a vote of thanks to the author, said asphalt was of great interest to engineers, especially to those who took an interest in municipal engineering. Such surfaces as roadways, footpaths, and roofs were now very frequently constructed of asphalt. Personally, he had not a large experience of making roadways.

There were one or two statements in the paper that he did not altogether agree with, and he would like to know whether they were borne out or not by experience.

One was the advantages of asphalt as a road surface over other materials as giving a surer foothold for horses. He believed it was the best method to adopt in narrow

roads and bye-lanes, but not in side roads or where there was a heavy traffic. He believed the experience of London and other large cities was that wood pavements had superseded asphalt to a very great extent in large thoroughfares. In the bye-ways and lanes there was, no doubt, nothing to compare with asphalt on account of the impervious nature of its surface and the ease with which it can be cleaned.

With regard to roofing, he had considerable experience of asphalt, and found the results very satisfactory. When properly laid it was undoubtedly a valuable material, and had some advantages over other kinds of roofing materials.

He would be glad to hear more particulars about the refining of the asphalt. He understood from the paper it was done by forcing heated air or steam through the molten mass. He would like to know if by this process alone it was brought to the commercial material which they saw on the market.

Mr. Bergin, in seconding the vote of thanks, said they were all accustomed to use asphalt in some form or other. The paper they had just heard read would, therefore, prove both useful and interesting, as it contained such a vast amount of information about its composition, nature, and manufacture. He would like, however, to ask the author what he meant by asphalt cement. He had never heard the term before, and he was sure it was new to a good many other Members present. He would be glad of a definition of it, and also more information about the process of refining.

As regarded asphalt for road-making, he quite agreed with Mr. Ross that it was an excellent material to be used in roads where there was not very heavy traffic, but where there were heavy grades it was not so satisfactory—in fact, it was rather dangerous.

Mr. Hargrave asked why Portland cement was used on the surface of the pavement before the light hand-roller went over it. Portland cement was very expensive, and he would like to know why sand was not used instead of cement, as it was very much cheaper.

Mr. Ruddle asked the author if he could give them more information about the King's Road maintenance cost. The paper stated that sixty-three yards were repaired during nine months. If they knew the surface area of the King's Road they would be able to work out the proportion of cost of maintenance per square yard of the road laid on this system.

Mr. H. T. Harris said asphalt pavements should certainly appeal to all cleansing departments of cities, for they undoubtedly were the easiest cleaned of all. The author should have made more out of this advantage. Wood pavement absorbs water, and quickly gives it off again in dry weather, and then dust. He thought from a health point of view engineers should put some value on asphalt for roadways. The question of public health was of great importance, and in a city like Dublin, where they had so much wet weather, they should take this into consideration when constructing pavements. It took an enormous amount of water to wash some of their streets clean, and this would not be the case with asphalt. These points should be considered along with the others of maintenance and cost of cleansing.

The President said that the analyses of the asphalt as given by the author were not very clear. He could not understand what was meant by "dust" or "filler," or by "white and yellow sand." The chief point about sand was that it should be perfectly clean, and for this reason the best sand for concrete was sea sand, though for house building sea sand was objectionable on account of the

salt it contained. Would this be objectionable in asphalt? Much also depended on the fineness of the sand. For some purposes the coarser the sand the better. With reference to the tests by passing through a sieve, it was not clear what was passed through the sieve—whether the sand, or the cement, or the asphalt.

The reason he asked these questions was that he wished the paper to be perfectly clear when it appeared in their "Proceedings."

It was a very curious thing altogether, this crater of an extinct volcano filled with this bituminous material, and the wonder was it had not been burnt out altogether. Another curious point was the height at which it stood above the sea.

With regard to the facility of repairing the asphalt surface when broken up for pipe laying, &c., the author stated that it could be done so well that the patch would be indistinguishable. If this is really the case it was a great advantage over other pavements. The way in which newly laid down streets were broken up for pipe trenches was a dreadful nuisance, and it was almost impossible to satisfactorily make good the surface. He would like to know the cost per square yard of constructing a considerable length of new road, say, not less than a thousand square yards, and the average cost of maintenance over a term of years. What was the duration of such a road?

Mr. Foley, in reply, said—With regard to the value of asphalt as a pavement from a sanitary point of view, it was a question more for the medical faculty than for them. In wood pavements there was no doubt that water went down between the joints, and when this evaporated in dry weather they were told that bacteria went with the evaporation.

With regard to the value of Mastic asphalt for roofs, it was very useful for these, but it was altogether a different article to the coal-tar which had been mentioned. The asphalt is refined by putting it into large tanks and heating to a temperature that will not injure its qualities, but which will remove all the foreign matters, such as bits of trees and vegetable matter. After this it is put into barrels.

In the making of cement the asphalt is mixed with petroleum residuum or shale oil and then agitated for about twenty-four hours, after which process it is called asphalt cement, and is packed in barrels.

He had described in his paper how the pavement mixture was made in the measuring boxes at the works and brought to the road where it was to be laid. Different materials were used in different places according to local circumstances, &c. Sometimes they used ground chalk, lias lime, fine sand, and Portland cement dust. The half white and yellow sand was Aylesbury sand. The white was as white as snow, and the yellow as yellow as gold.

With reference to the analysis, this was all done in the laboratory. The bitumen was extracted and the aggregate broken up, and then put through the different meshes, from 200 to 10, as described. It would be nearly impossible to make a standard price for new pavements, as each case depended on its own circumstances and the traffic that it had to provide for, as well as the period of guarantee required by public bodies.

With reference to joints not being distinguishable, he had the experience of laying or reinstating hundreds of yards of patches after the various company's cuts in the pavements, and he guaranteed that no man

living, after some traffic had passed over the street, could ever find a joint. The King's Road, Chelsea, surface area would be about 4,000 to 6,000 superficial yards. 11s. 6d. per superficial yard would be about the average cost of laying a road where all the materials are easily obtainable at reasonable prices.

[5th February, 1908.]

Mr. J. H. Moore, President, in the Chair.

The following candidates were balloted for and duly elected:—

James Nicholas Down, as an Associate Member.
John A. Ryan, as an Associate Member.
Patrick R. Morris, as an Associate Member.
Frank E. Sparrow, as an Associate.

Kildare and other Sewerage Works.

By Francis Bergin, Member.

The Kildare Sewerage Works were commenced in the year 1900, and as the purification works were one of the first, if not the first, carried out in Ireland on what is known as the bacterial system they have been selected as the principal subject of the following paper:—

The town of Kildare is, as most of the Members of this Institution are aware, situated on the Great Southern and Western Railway, thirty miles south of Dublin and within two and a half miles of the Curragh Camp. The town proper had a civil population in the year 1890 of 1,172, which had increased to 1,576 in the year 1900, or by 34 per cent. It is, therefore, one of the few towns in Ireland which can boast of an increasing population.

The boundary of the town, as defined in the rate-books, is of very limited extent, and does not include either the railway station or the majority of the pretty villas erected in the vicinity during the past few years, most of which are included in the drainage area, so that the actual civil population accommodated by the sewerage

system must be considerably in excess of that given above, and may be roughly taken at about 1,700. In addition to the civil population there are large military barracks in the town, erected during the year 1901, which are occupied by six batteries of the Royal Field Artillery, and afford accommodation for about 600 horses and 1,100 men, with their wives and families, and as all the barrack drains, with the exception of those constructed for conveying the water flowing off squares and roads to the nearest field drain, are connected with the town sewers, the entire population contributing to the outfall works may be taken at about 2,800.

The town is built on a ridge running nearly due west and east, the summit of which is indicated by a shaded line, marked X Y, on Drawing No. 1. This drawing also shows the position of the outfall works, the surface levels at different points, and the lines of main sewers. The disposal works are situated on the south side of the town, a little more than half a statute mile from the market house, to which the sewage is conveyed by two outfall sewers, marked Nos. 1 and 2, forming a junction at the point A, or southern angle of the plot of land acquired for the disposal works.

Outfall Sewer No. 1 is 12 inches in diameter. It is laid along the Council's accommodation road at a grade of 1 in 386 as far as the point B, and continues to Manhole No. 6, situated about one furlong south of St. Bridget's Chapel, from which point it branches in two directions. One of these branches, marked Main Sewer No. 1, mainly 9 inches in diameter, runs past the chapel and across what was formerly the Old Pound Green, now the site of the Electric Power Station, to the cross roads at "C," locally known as the "Cross Keys." The other branch, also 9 inches in diameter, is laid along

the side of a hill in front of the convent and county infirmary, and is continued to Manhole No. 12, where the military sewer provided for the southern portion of the barracks connects with it. These two main sewers receive the sewage from the whole of the town south of the shaded line X Y.

Outfall Sewer No. 2 is also 12 inches in diameter, and laid at a grade of 1 in 400 as far as Manhole No. 15, from which it is reduced to 9 inches in diameter and continued in a northerly direction as Main Sewer No. 3, at a grade of 1 in 300, to Manhole No. 22 on the Newbridge Road, where it wheels to the left in a south-westerly direction, passes through the barracks, crosses the road to the railway station opposite the new Railway Hotel, and terminates at Manhole No. 30. This sewer is one and a half miles in length and drains the whole of the town situated on the north side of the shaded line X Y.

An automatic flush tank, having a capacity of 750 gallons, has been provided at the head of each main sewer. Those on Main Sewers Nos. 1 and 2 keep these sewers clear of obstruction and in efficient working order, but owing to the great length and flat grade an intermediate one would be required on Main Sewer No. 3, and will probably soon be constructed at Manhole No. 22 on the Newbridge Road.

Three storm overflows have been provided for the purpose of relieving the sewers after heavy rainfalls—viz., one at the head of Main Sewer No. 1, one on Main Sewer No. 2 where it crosses Blindwell Lane, and one on Main Sewer No. 3 where it crosses the Newbridge Road. The first-mentioned is placed on an old sewer which receives the drainage of the north side of Claregate Street and portion of the Market Square, including the road drainage, and is now connected with the new system at

Manhole No. 1. This overflow, owing to the road water being admitted into the old sewer, comes into action frequently, but the other two very rarely.

With the exception of the old sewer in Claregate Street, constructed some twenty-five years ago, the sewers receive only yard drainage together with portion of the roof water, in addition to the sewage proper, and have, therefore, been designed on what is known as the "Partial Separate System." It was originally intended to drain that portion of the town lying north of the shaded line X Y by an extension of Main Sewer No. 2, otherwise the grades on this could have been considerably improved; but while the works were in progress the War Department purchased the land now occupied by the barracks, and as the proposed extension referred to would have seriously interfered with the laying out of the barrack buildings an arrangement was come to between the War Department and the District Council by which this extension was abandoned, and Outfall Sewer No. 2 with its extension, Main Sewer No. 3, constructed instead. The War Department contributed £300 towards the additional expenditure rendered necessary by this alteration, and agreed to take a supply of water from the Council, for which they have been paying £547 10s. per annum for the past five years.

It might appear at first sight that Main Sewer No. 3 followed an unnecessarily circuitous route; but land is very valuable about Kildare, especially building sites, while villas are springing up in all directions on the Curragh side of the town. It was, therefore, a matter of the greatest importance that this sewer should be set out so as not only to avoid crossing suitable building sites obliquely, but that it would also be capable of draining all sites on which buildings may hereafter be erected.

Drawing No. 2 gives longitudinal sections of Outfall Sewer No. 1 and Main Sewers Nos. 1 and 2; while Drawing No. 3 gives a longitudinal section of Outfall Sewer No. 2 and Main Sewer No. 3.

It will be observed on looking at Drawing No. 2 that the surface levels are extremely irregular, particularly between Manholes Nos. 6 and 14. At the former the depth to invert is only 5½ feet; at a distance of only 500 feet from this point it is 31 feet, while at a further distance of 500 feet the invert of the sewer is actually one foot over the surface of the ground. In fact, in order to avoid raising about 300 yards of the public road to the extent of about 5 feet, which would have added considerably to the cost of the works, the sewer was diverted from the road at Manhole No. 12A and laid at the back of the road ditch for a distance of 1,000 feet, where the ground was between two and three feet higher than the road and permitted of being raised where necessary for the purpose of protecting the sewer without causing any except a temporary inconvenience to the occupier of the lands—the late Mr. F. Lee, who, unlike others in the district, did not apply for even the ordinary way-leave compensation. The diversion, therefore, resulted in a substantial saving to the Council.

In the case of the outfall sewer for Newbridge, now in course of construction, the author has adopted a similar device for overcoming similar difficulties. This sewer, which is one and one-third miles in length and 18 inches in diameter, will be laid at a grade of 1 in 900, partly in cutting and partly in embankment, as shown on the longitudinal section (Drawing No. 3). Owing to the number of bye-roads and private roads that this sewer had to cross it was found impossible to set it out so as to entirely avoid raising some portions of the road along

which it is to be laid for its entire length, but by using cast-iron pipes at these crossings, and by laying the sewer wherever it rises above the surface of ground close to the back of the road ditch, where it will be protected by an embankment which will appear simply as an enlargement of the old mound fence, the alteration to the road surface, and therefore the cost of the works, have been reduced to a minimum.

Again, on looking at Drawing No. 4, it will be observed that the outfall sewer had to be laid for a distance of 1,000 feet from 5 to 10½ feet above the surface of the ground in order to reach the disposal works at the required level, which was accomplished by erecting an 18-inch masonry wall along the centre line of the old mound fence and carrying the sewer in a substantial concrete coping. This construction, so far as the author is aware, is of a rather novel character, and possesses some advantages. First, the ground which would have been required for the construction of an earthen embankment had not to be acquired; secondly, the material necessary for the construction of such an embankment could not have been obtained except from a considerable distance and at great expense; thirdly, the adjoining land was much less injured by the cartage of the material required for the wall than it would have been by the cartage of the material required for the embankment; and lastly, the wall forms a substantial and permanent fence between two adjacent properties—the Council's land extending on one side for nearly half its length.

The grades of the sewers are good with the exception of the first 1,000 feet of Outfall Sewers Nos. 1 and 2 (12 inches diameter), which are only 1 in 386 and 1 in 400 respectively, and the first 3,000 feet of Main Sewer No. 3 (9 inches diameter), which is only 1 in 300. These grades

are considerably less than are supposed to render a sewer self-cleansing, and it was with grave misgiving that the author decided to adopt such a flat grade as 1 in 300 for nearly three-quarters of a mile of sewer only 9 inches in diameter. There was no alternative, however, but to shift the sewer to a position in which it would not be available for the effective drainage of some villas already erected on the Newbridge Road and many sites likely to be built on hereafter—a course which, after mature deliberation, he decided not to adopt. The result has been most satisfactory, as the sewers have now been working for seven years, during which period there has been no stoppage or accumulation of deposit in either of the 12-inch sewers and only one serious obstruction in the 9-inch sewer. The latter was caused by a piece of timber becoming wedged so tightly between Manholes Nos. 18 and 19 that it could not be dislodged by the rods, with the result that the sewer had to be opened and cut. On two or three occasions some silt, consisting for the most part of coal dust and stable sweepings from the barracks, accumulated between Manholes Nos. 20 and 22, owing, most likely, to the velocity of the sewage being checked by the abrupt change in the direction of the sewer at these points. The deposits, however, were readily removed with the aid of the rods, and it is hoped that the construction of the proposed flush tank at Manhole No. 22 will prevent a recurrence of this trouble in the future. It is only right to mention that this sewer has to work under the most unfavourable conditions. It drains all the stables in the barracks as well as most of the married quarters, and although deep gullies of the most approved pattern have been placed at all points in the barracks where one could be required they do not appear to be effective in preventing such things as coal dust, stable sweepings, chopped

hay, soldiers' caps, sticks, cans, bottles, and the like from finding their way into the sewer.

Of course it is not desirable to use such flat grades as those mentioned if they can be avoided, but it may be an advantage to some Members of this Institution to know that under ordinary circumstances sewers having similar grades can be adopted with safety where better ones cannot be conveniently obtained.

The manholes and flush tanks are constructed of Portland cement concrete, mixed 6 to 1, and are of the usual type.

Considerable difficulty was experienced in selecting a site for the disposal works, which would be situated at a suitable distance from the town, to which the sewage from the whole of the district proposed to be served could be conveyed, and which would be so situated as to render the pollution of the source of the water supply to the town a physical impossibility.

The town is, no doubt, built on a ridge of considerable elevation, the level of the market square being 365 feet over Ordnance datum, but the ground falls rapidly, as will be observed on examining the levels given on Drawing No. 1 and the sections given on Drawing No. 2, and then rises again in all directions except along the valley marked D E F, in which St. John's Well, the source of the town water supply is situated. The stream D E F is fed by numerous springs coming both from the west and the east, but mainly from the latter, and was employed until recently to drive a pair of turbines erected at F for the purpose of pumping the water to the town. A few years ago the author carried out some works for the purpose of supplementing the supply to these turbines, when it was found that the springs on the west of the stream D E F, near the latter point, which were

running to waste at the time into the tail race, would not rise to the same level as those coming from the east. He, therefore, came to the conclusion that the springs on the two sides of the valley were not in communication with each other, and that the distribution of sewage effluents over a properly formed and effectively drained plot on the west side could not lead to the pollution of the springs on the east side, especially those in St. John's Well, the natural overflow from which is 1 foot 9 inches over the water level in the stream at the point E.

The plot marked A G D was, therefore, selected for the disposal works. It has now been continuously in use for the past seven years, and the experience gained during that period has fully justified the conclusion which led to its selection, as the quality of the water supplied, both to the town and to the barracks, is as good now as it was before the sewerage works were commenced.

The plot A G D contains three statute acres, the greater part of which has been laid out for irrigation purposes, and thoroughly drained to a depth of three feet. The drainage of the plot was originally conveyed through a 9-inch water-tight pipe drain and discharged into the stream at the point E (Drawing No. 1), where the overflow from St. John's Well also enters it, but the owner of Tully House—Colonel Hall Walker—being desirous of having it carried past his ornamental ponds, provided the money for the construction of a new outfall drain from the manhole at D to the point H (Drawing No. 1), at which the drainage of the irrigation plot is now discharged.

At first it was intended to sewer only the south-western portion of the town. Under the threat of an injunction and in order to purify the sewage from this small area the two tanks marked Nos. 1 and 2 and the two filters

marked Nos. 1 and 2 (Drawing No. 5) were constructed, but these only come into action at present after heavy falls of rain or when the large tank, No. 3, is being cleaned.

The disposal works as they now exist may be described as follows:—

The two outfall sewers terminate at the points A and B (Drawing No. 5). From these points the sewage flows in open concrete channels, 12 inches wide, to the grit chamber D E, and from the grit chamber to Septic Tank No. 3, which it enters through the two submerged inlets G and H. The effluent from Septic Tank No. 3 enters the channel I J through the submerged outlet shown, flows through what is called a humus pit, J K, and at the point L enters the channel L M, which feeds the Contact Beds Nos. 1, 2, 3, and 4. The effluent from the contact beds is discharged into the channel N O, from which it is conveyed by the channel P Q R S, and distributed over the several plots into which the irrigation ground is divided.

A notch plate is fixed on the outlet from the grit chamber which will only allow six times the dry weather flow to pass through, anything in excess of this being sent over the storm overflow weir C D and conveyed by the channel S T to the storm water filter effluent channel U V, which discharges into the outfall drain through the manhole shown at N (Drawing No. 6).

At the point F (Drawing No. 5) another notch plate is placed across the channel, which only allows three times the dry weather flow to pass through, with the result that the difference between six and three times the dry weather flow passes over the weir E F and is conveyed by the upper channel W X to a small sludge tank X Y, from which it is distributed over the storm water filter. There is also an overflow weir provided for the channel I J,

which is connected with the upper storm channel W X, and comes into action in the event of the automatic feeds to the contact beds failing to act or being overworked.

Septic Tank No. 3 was constructed at a time when it was hoped that such tanks would liquefy the whole of the solid constituents of sewage, and hence was left without any sludge outlets; but unfortunately we all now know that these tanks liquefy only a small proportion of the solid organic matter—namely, about one-third—that about one-third of it remains in the tank as sludge, and that the balance is carried over in the effluent which is passed through contact beds or filters, rapidly reduces their capacity, and after a time leads to their becoming almost completely choked or sludged up, especially if formed of finely-grated material.

The tank under consideration was originally constructed as shown on Drawing No. 5, and was run continuously for three years without being cleaned. At the end of this period it was found that the capacity of the beds had been reduced to nearly one-seventh of what it was when they were first started, and that the tank after beng allowed to settle contained three feet of thick mud uniformly distributed over the bottom. The filling of the beds had, therefore, to be taken out and washed at very considerable expense while the tank was pumped out and thoroughly cleaned.

Since the beds and tank got the above general cleaning a division well was constructed near the inlet end, and the outlet changed to a long weir with an obliquely-set scum board in front of it—the tank as it now exists being shown on Drawing No. 7. A chain or sludge pump was also erected near each end of the tank and a humus pit constructed between the tank outlet and the beds for the purpose of arresting as much as possible of the finely-

divided solid matter contained in the effluent from the former.

These alterations and additions have been attended with marked success. The inlet end of the tank is pumped out regularly—about once every three months—by the caretaker with the assistance of a labourer for a couple of days. There is practically no deposit in the outlet of the end of the tank, and no humus is deposited on the surface of the beds which, in place of being sludged up after the first three years' use, are now, after a similar period, in thorough and efficient working order.

In refilling the beds the coarse clinker was placed on the floor for the purpose of assisting the drainage, which the author found to be necessary, while the finer material, to the depth of about one foot and graded between one-quarter and one-eighth inch, was placed on top, the object being to prevent as much as possible of the solid matter from getting into the body of the bed and to retain it near the surface, where the anærobic bacteria are most active.

The filling and emptying of the beds is regulated by Adams' automatic air lock feeds and timed discharging syphons. The apparatus gave some trouble at first, but has been working satisfactorily for the past three or four years.

By observing the time Tank No. 3 takes to fill it has been found that the dry weather flow of sewage to the works is at the rate of 36,782 gallons per day.

The effluent from the contact beds is distributed over one and a half acres of land, divided into plots one chain wide, and thoroughly under-drained. Some material had to be removed from the surface of these plots last year, but the land is now working apparently as well as it was at first. An additional three-quarters of an acre was prepared and under-drained in order to meet the requirements of the

Local Government Board, but it is absolutely useless; it is never used, and shows clearly how absurd it is to go to the expense of acquiring and laying out any except suitable land.

Mr. Kaye-Parry, in proposing a hearty vote of thanks to Mr. Bergin, said he did so with pleasure, because it was just the style of paper which they wanted. The author had given them the results of his own experience, the difficulties he had met, and how he had overcome them. All these were of great interest to men who had to face these problems themselves. That type of paper was very useful in an Institution like theirs, and was especially interesting to the younger members. He had an opportunity of going over the works at Kildare, and he could testify to the fact that they reflected great credit on Mr. Bergin, having regard to the time at which they were erected. There were one or two points in the paper which he would like to speak about. One of these was with reference to the gradient of sewer pipes. The author need not be uneasy about the 9-inch pipes which had a gradient of 1 in 300. The velocity of the flow in these pipes when half full would be about 140 feet per minute, or nearly $2\frac{1}{2}$ feet per second. His experience was that a 9-inch pipe with a gradient of 1 in 300 would work very well. A good many years ago he put in one at Abbeyleix with exactly the same gradient, and, as far as he knew, it had never given any trouble since it was laid.

According to the text-books a gradient of 1 in 386 for a 12-inch pipe was sufficient, and it gave a velocity of about 150 feet per minute.

He thought all the gradients Mr. Bergin had adopted were adequate, and he would not hesitate to use them

where the conditions were similar to those which the author had to meet in Kildare.

The author had told them his time syphons had given him some trouble. He, the speaker, had some personal experience of these syphons, one set causing him a lot of trouble for a long time, though he had got them right at last. But he had also put some down at Armagh which worked well from the very start.

It was very satisfactory to hear that the dry weather flow of sewage at Kildare was only thirteen gallons per head per day. In a great many towns the quantity of sewage discharged at the outfall was a great deal more than the water consumed in the town. This was sometimes believed to be the result of subsoil water getting into the pipes. The small volume at Kildare would go to show that the pipes laid down by Mr. Bergin must be perfectly water-tight and did not admit any subsoil water.

With regard to the question of sludge, the author had told them that when the septic tank was made in 1900 they all hoped that there would be no sludge in it. This opinion may have been held by a great many people, but the speaker took the credit to himself of having a different one.

At Leeds in 1897, during a very important discussion, he had stated that as long as they had sewage they would have sewage sludge to deal with. At the same meeting Mr. Cameron described his septic tanks, and Mr. Dibdin spoke of contact beds. Both of these gentlemen then asserted to a very large audience that the sludge difficulty had been overcome. Unfortunately for themselves, a good many people believed this statement, for shortly afterwards Mr. Dibdin erected some contact beds which

sludged up very rapidly, with the result that the installation would not work.

Dr. Owen Travis, of Hampton-on-the-Thames, had issued a pamphlet showing the defects of the contact beds at that place. After a persual of his writings they would probably form the opinion that they had not done what was claimed for them.

The speaker held that putrefaction was not a necessary preliminary to the purification of sewage, and that if they took steps to separate the solids without a septic tank, and adopted ærobic filtration, they would be able to get a good effluent.

The author, however, had not given them a description of the results of the treatment, what the effluent was like, and what purification had been actually effected. This was the principal information they required. They were not all chemists, and hitherto they had had some difficulty about getting such information in a form which they could use.

Anyone who was present at a recent scientific meeting of the Royal Dublin Society would have heard a description of a very simple apparatus which Dr. Adeney had designed to enable engineers and others to examine the condition of any effluent. This apparatus will also tell what amount of purification had been effected without the use of any chemical formulæ. It is very simple, and a firm of manufacturers have taken it up, so it will be very soon on the market, and he believed that they would all find it extremely useful. He was sure that all engineers engaged in this work would be very grateful to Dr. Adeney for placing it in their hands.

Mr. Hargrave, in seconding the vote of thanks, said they were very much indebted to the author for his paper and the diagrams which he had gone to the trouble of

making. He could not say very much upon the paper, as the subject was outside the scope of his work, but would like to refer to a few points.

The author stated there was an automatic flush tank of about 750 gallons at the head of each main sewer, but he did not tell them how often these tanks were flushed. He also mentioned that the sewer pipes were carried for portion of their length on the top of a wall 5 to 10½ feet above the surface of the ground. He would like to know if any provision was made to protect the pipe from the changes of the weather. In cold, frosty weather they might get a coating of ice inside the pipes which in case of a prolonged frost might cause trouble.

With regard to the fall of 1 in 300 in a 9-inch sewer, the author said he would like a steeper fall if he could get it, and so would everybody, but it was pretty safe.

Some twelve years ago he had to erect a system for carrying sewage, &c., from a station and engine-shed where there was a quantity of fine ashes, and they had to use a gradient of 1 in 290. They did so in fear and trembling, but it had worked well ever since with only one slight stoppage.

Mr. P. H. M'Carthy, in supporting the vote of thanks, said the paper was a very practical one, and appealed in an especial manner to all engineers. There were just one or two points about which he would like some more information. One was the capacity of the filter-beds. The liquid capacity is generally about one-third of the total volume of the filtering material. That was about the normal working condition of the filter. It might possibly be reduced to one-fourth or one-fifth of its capacity. If reduced less than this—to, say, one-twentieth, as in the present case—it was simply a mass of solid sludge. He would like to know how many gallons per

day passed through the filters per cubic yard of filtering material, as, of course, if the liquid was passed through at too high a rate it might account for the sludging up to some extent. With regard to the sewers, he would like to know if any small sediment settled at the bottom and if they had to use the rods frequently to keep the sewers clean. If rods were used pretty freely it would be easy to keep the sewers clean, but a rather expensive way. He would be rather apprehensive of smells with surface ventilation and sediment in the bottom of the sewer. The flushing tank of 750 gallons at the head of a sewer over a mile long would do for the pipes in the upper end, but it was practically useless for the lower portion. They would want three flushing tanks at least to keep the entire length fairly clean with frequent discharges. He noticed the author approved of the slate beds. He had an opportunity of inspecting some slate beds in England. It was really marvellous to see the work these slate beds were capable of doing. The crude sewage was passed on to the bed, which is practically a development of the coarse-grain filter, and the effluent was remarkably free from suspended matter and suitable for further treatment on fine-grain filters. In connection with these beds it may be mentioned there was practically a total absence of smell when he inspected them.

Mr. R. M. Butler suggested that the Council should have photographic slides made of the more important drawings in future similar papers, as it would enable the members to understand the papers better. Half-way down the room it was impossible to follow the descriptions of diagrams. It would not be reasonable to expect the authors of papers to supply such slides at their own expense, but the Council might, perhaps, see their way to adopt this suggestion.

He thought with Mr. Kaye-Parry that the author had no need for fear as to the gradients of 1 in 300 for 9-inch pipes, for in practice such grades were found to work out all right. About eighteen months ago he had put down a long length—850 yards or thereabouts—of 15-inch pipes at 1 in 1,000, and they were still perfectly clean, although a rod had never been used on them. He thought the author was rather pessimistic about the utility of tanks. Tanks and the results attained were greatly governed by circumstances. In some cases one got a great deal of sludge, while in other—the majority—instances they got but a very small amount. The results absolutely depended upon circumstances.

With regard to filter beds, there was a theoretical idea as to the fineness of the filtering material, but he found better results were got from filtering materials coarser than the theoretical grade.

In small installations there ought not to be very much trouble in cleaning the beds. If they had a good supply of clinker or other filtering material on hand the cleaning process could be readily carried out without interfering seriously with the works.

With reference to the slate beds, to which Mr. M'Carthy had referred, he had had some correspondence with Mr. Dibdin in regard to the use of these, and later on Colonel Dickenson (formerly of Dublin), who was interested, assured him that they were absolutely practicable, and that he had lain down his full length on one of them and could not get any objectionable smell from the slate bed.

These beds yielded a sludge that was a dark, mossy substance, and looked like peat, with a slight earthy smell.

THE PRESIDENT said he took some of the credit for having this paper brought forward, as he had asked in his Address.

that papers should be brought forward giving descriptions of the sewers and waterworks which were being constructed in the smaller towns throughout Ireland. The works at Kildare presented some peculiarities, both as regards the very flat gradients and the ingenious way in which the sewer was carried overground across hollows.

The outfall sewer at Navan was a 12-inch pipe, with a gradient of 1 in 400, and worked very well. A stoppage had occurred on one occasion which, like that at Kildare, was caused by a short piece of wood, just longer than the diameter of the sewer, getting jammed across. A great deal of extraneous matter seemed to have got into the Kildare sewers which he thought might have been kept out by proper gullies.

He would ask Mr. Bergin to add some particulars as to the cost of the works, which was always interesting and of paramount importance to the ratepayers who had to pay for them—that is to say, the total cost and the rate per head both for the sewers proper and the purifiers. The question was—Was it possible to purify sewage at a reasonable cost? Up to the present, sewage purification works had not turned out as satisfactory as was anticipated. He would also suggest that analyses should be made (*a*) of the crude sewage as delivered on the filters, (*b*) after passing through them, and (*c*) of the effluent delivered into the stream after passing through the land.

Mr. James Dillon said the town of Kildare was built on high, dry land with a small sewage discharge in summer favouring sewage deposit in a long length of sewer pipe. He had executed some works further down the country, and he found it was a very dry country as regards subsoil. He would like to ask the author what was the effect when they had a heavy downfall of rain? Did it not tend to choke the sewers owing to the dry

weather deposit that might have collected in the sewer pipes during the very dry weather, thus acting as an obstruction during the flow of the flood waters through the sewer pipes?

Mr. Bergin, in reply, thanked the members for their hearty vote of thanks and the manner in which they received his paper. With regard to the gradients of the sewers, these had worked satisfactorily, the rods having had to be used only on three or four occasions during the past seven years, and at only one point—viz., at the Newbridge Road crossing, where there are two right angle turns in the sewer—but he found that a good deal of deposit accumulated, especially in some of the manholes, which was carried down to the outfall during heavy falls of rain and delivered over the storm water filters, necessitating the frequent cleaning of the latter.

The trouble referred to in connection with the automatic feeds of contact beds supplied by Messrs. Adams & Co. was caused by what are called the auxiliary syphons. When the apparatus was first fixed these syphons were required to fill the air dome pits by syphoning over a sufficient quantity of liquid from the beds when the latter became full, and afterwards to empty these pits according as the beds were discharged. They failed, however, to act in this double capacity, with the result that a bed was frequently found to be filling and discharging at the same time, and consequently working as a continuous filter in place of a contact bed. By altering the syphons so that they have only to empty the dome pits and by providing a short weir in the walls of pits for filling same the defect mentioned was remedied, and the apparatus has since been working satisfactorily in every way.

During the year ending the 31st March, 1907, 17,681,585 gallons of water were pumped to the town,

including the barracks, being at the rate of 48,000 gallons per day, but as fully one-fourth of this is used for washing the guns and waggons in the barracks, which does not find its way into the sewerage system, and for supplying districts outside the drainage area, it would appear as if the ascertained dry weather flow of sewage were practically the same as the quantity of water consumed. In some places the subsoil water increases the dry weather flow, but owing to the nature of the ground at Kildare no subsoil water has to be dealt with.

With reference to the character of the effluents, he had hoped to have given a number of analyses, but unfortunately he was unable to obtain these in time to embody them in his paper. He should mention, however, that the purification obtained in passing the effluent from the septic tank through the contact bed is about 70 per cent., and that although the effluent from the irrigation area has been discharged into a small stream for the past seven years no complaints of any kind have been received, so that practically the works are a complete success.

He was very glad to hear that Dr. Adeney had devised a simple apparatus which would enable engineers to analyse sewage effluents, as the custom now in vogue of sending samples to the county analyst was open to many objections.

With reference to flushing, the flush tanks are discharged once or twice a week according to the state of the weather, which has been found sufficient. Outfall Sewer No. 2 is laid in a substantial concrete coping. It is, therefore, encased in concrete, and has given no trouble during frost. The unsuitable land referred to was laid out in order to comply with the Local Government Board's Regulations when the second portion of the scheme was being carried out, but it is never used. The

land that is used, containing one and a half statute acres, has, therefore, been dealing with a dry weather flow of 36,782 gallons per day, being at the rate of 24,521 gallons per acre per twenty-four hours.

He would add an addenda to the paper giving the cost of the works.

ADDENDA.

The works comprise the construction of four miles of sewers, varying from 6 inches to 12 inches in diameter, 30 manholes, 3 inspection chambers, 10 lampholes, 3 flush tanks with disposal works, and have cost, exclusive of law costs and engineers' fees, £4,898. Of this sum £3,298 was expended on sewers, manholes, &c., and £1,600 on disposal or purification works, which included the purchase of land, the preparation and under-drainage of two and one-fourth acres of land for irrigation purposes, the construction of septic tanks, contact beds, storm water filters, concrete carriers, &c. The disposal works have, therefore, absorbed one-third of the entire cost of the works.

The alterations made in Septic Tank No. 3 resulted in all the heavy sludge being caught in the first compartment, while there is practically no deposit in either the second or third compartment. The author has therefore come to the conclusion that all septic tanks should be divided into two or three compartments, somewhat as shown on Drawing No. 7, and that where the fall permits the tank should be constructed of a capacity of only one-third of the dry weather flow, with a slate bed of adequate size to receive its effluent before the latter is discharged either on filters or on land prepared for irrigation purposes.

[4th March, 1908.]

MR. J. H. MOORE, President, in the Chair.

The following Candidates were balloted for and duly elected:—

R. H. RHIND, as a Member.

A. HALE, as a Member.

F. E. DRAPER, as an Associate Member.

THE PRESIDENT announced that the paper which was to have been "read" had been withdrawn.

[1st April, 1908.]

Mr. J. H. Moore, President, in the Chair.

The following Candidates were balloted for and duly elected:—

A. J. Downing, as a Member.

G. J. S. P. Kelly, as an Associate Member.

Description of the Works in Connection with the Proposed Additional Storage Reservoir at Roundwood, Co. Wicklow, for the Corporation of Dublin.

By John G. O'Sullivan, Member.

It having been pointed out that a paper in reference to the above works would be of interest to the members of this Institution, the author has much pleasure in submitting the following notes which are intended as an explanation of the accompanying plans.

A paper based upon the experience of difficulties encountered, and the means adopted for overcoming them, when dealing with large works of this description, would, it is considered, be more acceptable to the members. All that can be claimed is the indulgence of the members whilst this outline of the proposed works is placed before them, which, in consequence of the paucity of similar works of such magnitude in this country, must prove somewhat interesting, and it must be left to others to chronicle whether or not the suggestions now put forward have merited that success for which those responsible have striven.

As all the members of this Institution may not be

personally acquainted with the *locus in quo* of the works of our present water supply for the city, it might here be mentioned that they are situated upon the Vartry, a small river, only 17½ miles in length, which rises at the bases of the great Sugarloaf and Douce Mountains, in the County of Wicklow. From the time it emerges from the well springs on the sides of these mountains the natural course of the river is in a direction directly contrary to that in which the City of Dublin lies. From its source the river flows in a southerly direction, through a thinly-populated district of the County Wicklow, and in its course passes through the Devil's Glen, the picturesque village of Ashford, the Broad Lough, and flows into the sea at the town of Wicklow.

It is hoped that it will not be considered out of place if a brief reference is here made to the existing storage works at Roundwood, to which the proposed reservoir will act as an auxiliary or supplemental supply.

At a level practically of 700 feet over the sea, and close to the little village of Roundwood, the Corporation of Dublin, over forty-five years ago, constructed the existing reservoir and works. The point selected on the River Vartry as the site of the embankment to form the existing storage reservoir is about 7½ miles from its source, and about 1½ miles south-east of the village of Roundwood. The level of water in the river at this point was 632 feet above Ordnance datum and 520 feet above the highest part of the City of Dublin. When the reservoir is full to reduced level of 692.45, the area of land covered is 409 acres, the greatest depth being 60 feet, and the mean average depth 22 feet. Its storage capacity is about 2,400,000,000 gallons, or equal to two hundred days' supply for the City of Dublin and the suburban districts, at the rate of 12,000,000 gallons per day, or when the

movable planks are fixed on top of bye-wash, whereby an additional foot in depth of storage is obtained, there is two hundred and seven days' supply.

Two other embankments had to be constructed (the Knockatemple and Waters Bridge) to carry county roads across the reservoir; but the entire water is impounded by the one bank above described.

The reservoir and works are surrounded by a boundary wall of rubble stone 5 feet high, the base of which is carried round the reservoir on a contour line 6 feet above top water line. This wall is over eleven miles long, and encloses, including embankments, filter beds, and the lands purchased by the Corporation, 550 acres.

Some years ago the Corporation of Dublin were advised by the City Engineer, Mr. Spencer Harty, that the time had arrived when it was necessary to make provision for the additional drain imposed upon the storage works by the increased area of supply.

Mr. Harty, in addition to the many other pressing duties attaching to his office as City Engineer, holds the position of Waterworks Engineer, and from his long years of experience and practice (having been associated with the Vartry scheme since its inception) is recognised as one of the leading waterworks experts in the kingdom, and has repeatedly appeared as such in the witness chair before the Committees of the Houses of Lords and Commons.

In deference to his strong expression of opinion and advice, the Corporation acquired over 510 acres of land for the purpose of the proposed additional reservoir, and the author was subsequently directed to make the necessary surveys and sections, and prepare the contract plans.

The portion of the valley to be now submerged for the construction of the second storage reservoir is upon the

reach of the Vartry river immediately above the existing reservoir, and will extend in a northerly direction from the north end thereof towards the Sugarloaf Mountain, and will lie almost at the foot of the eastern slope of Douce Mountain.

The site of the new reservoir is about thirteen miles from Bray, and about twelve miles from the town of Wicklow—the total distance from Dublin being about twenty-five miles.

On the plan lodged in Parliament close on fifty years ago for the existing waterworks it was proposed to construct a compensation reservoir at a point lower down the river (at Annagollen Bridge), about two miles below the proposed storage reservoir, to provide water compensation against the claims of the millers and riparian proprietors on the river below. Fortunately, however, prior to the Bill going before the Parliamentary Committee, this reservoir was abandoned, and it was determined to give money compensation in lieu. By this arrangement the Corporation have become the sole owners of all the water which falls upon the catchment basin above their works, and no party has any right or title to use or divert any of it, with the result that now, many years after that date, when they have determined to supplement their storage, they are not faced with the expense attendant upon compensating or extinguishing any riparian rights.

Watershed.—The watershed or drainage area of the existing reservoir is 13,700 acres, all practically situated upon a plateau which stands at an altitude of between 700 and 900 feet over sea level, the district being something similar in shape to that of a saucer, being for the most part surrounded by hills. The catchment line or ridge forming the boundary of this area is highest upon the western side, where it extends up to the top of the

chain of mountains comprising Douce, and varies from 2,384 feet to 1,580 feet, whereas on the eastern side the altitude of the ridge varies from 1,200 feet to 800 feet.

As the new reservoir will be constructed at the upper, or northern, end of the existing reservoir, the gathering ground or catchment is accordingly reduced, and the area draining into the new reservoir when constructed will be 9,000 acres.

Freedom from Pollution.—It may be taken that there are very few gathering grounds within the United Kingdom, except those from which all human habitations have been removed, which are so free from the risks of pollution as is the catchment area of the Vartry. There are comparatively few human habitations within the catchment area, with the exception of the village of Roundwood, the entire surface and other drainage of which has been intercepted and carried away in a sewer constructed for the purpose, and which discharges into the river at a point below the filtering beds at Vartry Lodge. In addition, there is very little agriculture, and the proportion of bog-land is small.

Mr. Mansergh, in his evidence at the inquiry held by the Local Government Board in reference to this scheme, pointed out that on the catchment of the Thames it is calculated that there are 300 persons per square mile, compared with 30 persons per square mile in the Vartry catchment.

The committee appointed by the Local Government Board for Ireland in 1900, in their report upon the public health of the city, referred to the water supply, and stated they were satisfied that the Vartry water supply is of the most excellent quality.

Geology.—The geological formation of the entire drainage area is the lower silurian and Cambrian slate,

except on the tops of the adjoining hills to the west, where the granite crops out in spots.

The new reservoir, however, is situated entirely over the Cambrian slate formation, which has boulder clay of varying quality overlying it. The boulder clay on the eastern side of the valley is stiff and good, but that upon the western side contains an amount of silty matter.

The junction of the lower silurian with the Cambrian takes place some distance to the west of the proposed embankment and reservoir.

Upon the centre lines of the principal works trial pits were sunk, with the result that it was found the rock formation dipped slightly to the south at an angle of about 15 to 20 degrees. Along the centre line of the main embankment the bed rock level was reached at depths below the natural surface of the ground varying from 11 feet to 37 feet.

The level of the rock approaches nearest to the surface of the ground at the deepest part of the valley, so that the height of the embankment at this point, from the finished level to the level of the rock, is but 62 feet.

Area of the Ground Acquired.—As already stated above, the Corporation some years ago acquired 510 acres for the construction of this new reservoir, and when the level of the water in the reservoir will reach the crest of the overflow weir (738.00) 303 acres of the ground will be submerged.

Within the boundary fence of the new reservoir there are at present three dwellinghouses, which will be removed.

Dimensions of the Reservoir.—The total length of the boundary fence around the ground acquired amounts to seven miles, and this fence has been constructed as nearly as possible along the 744.00 contour line, being six

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feet over top water level. The maximum length of the new reservoir, measured from the centre of the embankment to the most northern point of the new boundary fence, is two and one-eighth miles. The maximum width of the ground is two-thirds of a mile.

Top Water Level.—The reduced level of the crest of the overflow or waste weir has been fixed at 738.00 above Ordnance datum.

Capacity.—The greatest depth of water in the proposed reservoir will be 44 feet, which will be at the embankment immediately over the lowest part of the valley. The mean average depth will be practically 16 feet, and the estimated contents of the proposed reservoir, when full to the crest of the overflow or waste weir, will be 1,259,000,000 gallons, from which must be deducted about 23,000,000 gallons which would be below the lowest draw-off (not including the scours), leaving available over 1,236,000,000 gallons.

By the addition of the new reservoir the total quantity stored and available will be 3,360,000,000 gallons, being 240 days' supply at the rate of 14,000,000 gallons per diem.

Diversion of Vartry River.—The first work which must be undertaken in connection with the construction of the new reservoir will be to divert the river in order to permit of the excavation of the puddle trench in the lower part of the valley. With this object in view it will be necessary to construct the eduction canal and tunnel as well as the bye-wash channel. In order to secure the works against all possible risks from flooding during their progress it is also proposed to construct at the same time the bye-wash tunnel and the temporary branch tunnel, as suggested by Mr. Mansergh, to both of which reference in detail will be made further on.

The danger likely to arise from flood-water during the rainy seasons whilst the works are in progress is necessarily a matter of grave consideration, and all the requisite precautions must be adopted, so that nothing may be left to chance.

The maximum flood which appears to have occurred in the Vartry valley during the past forty-five years took place in the year 1880, when 1 foot 5 inches was recorded upon the 300-foot weir. From calculations it has been found that this was equal to about 8.0 cubic feet per minute per acre over the 13,700 acres of drainage area.

The proposed works, however, at the suggestion of Mr. Mansergh are now designed to deal with a flood of 15 cubic feet per minute per acre over the restricted catchment area, and it is intended that in the event of a flood of such magnitude taking place, a volume equal to two-thirds thereof shall be passed through the eduction tunnel, and the remaining one-third through the temporary branch tunnel into the bye-wash tunnel.

The estimated flood of 15 cubic feet per minute per acre is practically double the flood of 1880, thereby leaving a very safe margin.

In addition to the above it will be found by reference to the Report of the Castletown Commission that from observations made by Mr. Robert Manning, M.Inst. C.E., on the eastern coast of Ireland the maximum flood discharges do not appear to have exceeded 3 cubic feet per minute per acre.

In addition to the construction of the temporary branch tunnel above referred to it is proposed to construct a large temporary stank or dam across the valley about 300 feet up stream of the line of the main embankment.

This stank will be 500 feet in length, and will be 18 feet in height. It has been calculated that this will be

more than enough to secure the works in the trench even though the temporary tunnel was not constructed.

However, the cost of adopting these temporary precautions is but a fraction of the entire cost for the permanent works, whereas the satisfaction of the engineers will be great indeed if they ever experience during the progress of the works a flood of the estimated amount of 15 cubic feet per minute per acre.

As has been already stated above, the first part of the work to be undertaken must be the eduction canal and bye-wash channel, which will during the progress of the remaining portion of the work really form the diverted course of the River Vartry. The eduction canal will, therefore, serve a double purpose:—

First, it will act as a river diversion during the construction of the embankment, and must, as in the case of the bye-wash, be of sufficient dimensions, and have a sufficient fall to convey with safety, and without undue erosion of its bed or banks, the maximum quantity of water that may be delivered into it by the Vartry river at the point of diversion.

Second, it will, after the completion of the embankment, act as a feeder to the eduction tower when water in the reservoir is low, and also as a means for scouring.

The first-mentioned requirements are very much more exacting than the latter. The dimensions of the canal have been made to suit the former. In other words, the eduction canal and bye-wash have been designed to secure the same discharging capacity.

The eduction canal will be 21 feet in width, with a gradient of 1 in 785 in earth, 1 in 320 in rock, and slopes of $1\frac{1}{2}$ to 1. For a distance of 980 feet it will be entirely in earth, and for 780 feet the channel will be entirely through rock.

The strength of a chain being adjudged by that of its weakest link, it was necessary that a similar standard should be applied to test the efficiency of the design for the proposed works. It has been found from experience that the weakest link in connection with the successful completion of the works for a new reservoir lies in the manner in which the eduction opening under the line of the embankment is constructed. There are instances in which, owing to the configuration of the valley, it has been found possible to construct such openings perfectly clear of the line of the embankment, by taking the draw-off tunnel, or culvert, through the natural ground on the side of the valley.

Undoubtedly, such a method of construction would be the best, as the impounding embankment would then be free from all risk of any settlements likely to arise from defects in the construction of a masonry culvert.

However, in this scheme the next best step has been taken, and the draw-off tunnel will be constructed in the solid rock, so far removed from the centre of the valley as to be nearly clear of the line of the main embankment. With the superincumbent rock it is confidently felt that no anxiety need exist of any trouble being likely to arise from this source. Apart altogether from the sense of stability which a tunnel through rock naturally inspires, there is also this further and most important advantage—that the efficiency of the puddle wall will in no way be interfered with, inasmuch as the tunnel will pass through the rock far below the level to which the puddle wall will be carried. If the eduction culvert had to be constructed of masonry across the longitudinal axis of the main embankment it would set up a number of weak spots in the puddle wall. By the adoption of the present arrangement the puddle wall will be one large

homogeneous and compact mass for its entire length across the valley.

The eduction or draw-off tunnel will be 350 feet in length. The invert will be flat, and the roof or arch will be semicircular. The tunnel will be 15 feet in width and 13 feet 6 inches to the crown of the arch.

The floor or invert of the tunnel will have a gradient of 1 in 785, and under head will discharge 10 cubic feet per acre per minute. This, as has been pointed out above, will only be two-thirds of the estimated maximum flood discharge of 15 cubic feet per minute per acre. The lessening of the discharge through the tunnel was unavoidable in consequence of the proximity of the line of the proposed embankment to the existing reservoir, and to the desire to maintain the maximum thickness of rock in the arch of the tunnel. Accordingly, in designing these works very great difficulties had to be overcome owing to the small differences of level between the up-stream side of the embankment and the present reservoir.

Throughout the entire time that the design of these works was under consideration it was necessary to keep well to the forefront the necessity for providing for the river and winter floods during the progress of the works, in addition to securing the maximum efficiency for the works of permanency after the completion of the reservoir. Hence it was found in many cases that what would be expedient in the former case would be most unsuitable in the latter.

Amongst other things, therefore, which had to be resorted to during the time of the designing of these works was the cutting away or sinking of the rock forming the invert or floor of the tunnel to a depth of 6 feet below the gradient line joining the points of the invert immediately above and below the tunnel.

By the adoption of this sump, or sunk area, for the entire length of the tunnel the effective depth of rock for cutting the tunnel through will be from 27 to 30 feet, measured from the invert.

When the eduction and scour pipes are laid in position a wall will be built across the southern, or outlet, end of the tunnel, so as to prevent water from the bye-wash entering into the eduction tunnel.

Upon the completion of the tunnel the sides and arch will be lined with brickwork in cement, the inner ring being of blue Staffordshire brick. Spaces between the brickwork and the rock will be filled in with concrete. The floor or invert of the tunnel will be laid with concrete after the pipes are placed in position.

Upon the completion of the works the inlet, or upstream, end of the tunnel will be sealed with a plug consisting of masonry in cement 14 ft. 6 ins. in thickness and blue Staffordshire brick in cement 18 inches in thickness.

In immediate connection with the eduction tunnel will be constructed the eduction tower, in which will be placed the draw-off pipes. This tower will be built upon the rock forming the crown of the arch of the tunnel, and it will stand at a distance of 28 feet from the inner face of the plugging.

The rock within the area covered by the flood of the tower will be removed, thus forming a direct and clear pasage from the tower into the tunnel underneath. Unlike the existing tower on the present reservoir, this will be a dry tower with a 33-inch vertical draw-off pipe carried up in the centre thereof. By the adoption of this design of tower and tunnel the eduction and scour pipes, with all the draw-off connections and valves, will be completely exposed to view, and rendered easy of access for constant inspection.

Iron platforms and ladders will be provided for ascending and descending through the tower. The efficiency and safety of the draw-off connections will, in addition to the ordinary valves inside the tower, be further secured by penstocks upon the outer facings.

As I have already stated, the bye-wash channel must be constructed concurrently with the eduction canal and tunnel before the embankment work can be proceeded with.

This channel will be, for the greater portion of its length, cut out of the solid rock, and will be merely in soil for a short length where it adjoins the existing reservoir.

It will be 30 to 40 feet wide in the rock, except at the point immediately south of the two tunnels. It has been designed to discharge the estimated maximum flood discharge of 15 cubic feet per minute per acre, which it is calculated will rise from 6 to 8 feet in the rock cutting.

As has been pointed out before, the construction of the bye-wash tunnel must be undertaken as one of the primary works, in consequence of the part which it is proposed it shall play as a flood-water overflow. In the event of experiencing the full effect of the estimated maximum flood discharge the bye-wash tunnel will provide for the remaining one-third of the flood water, the first two-thirds being discharged through the eduction tunnel.

The bye-wash tunnel *per se*, however, is primarily designed to convey the maximum flood discharge of 15 cubic feet when the reservoir shall have been completed, as it is only by this means that the flood or waste water can then be disposed of. This tunnel, cut through the solid rock, will be 15 feet in width, with a flat invert and a semicircular arch or roof. The height of the tunnel will be 12 feet to the crown of the arch. The gradient

through the tunnel will be 1 in 900, and is calculated to discharge the full flood under head.

A consideration which played an important part in determining the adoption of a tunnel for a portion of the length of the bye-wash was that the continuity of the puddle wall for its entire length across the valley would be maintained unbroken, thereby securing its maximum efficiency intact.

The natural tendency in designing an overflow weir and waste-water or bye-wash channel without much consideration would be to make the waste-water pass over an open weir on the line of the embankment and then down an open channel constructed on the down-stream side, protecting the course of the flow of the water with heavy masonry in cement; and, as a matter of fact, overflow weirs and bye-wash channels are largely constructed in this manner. It is far preferable, however, to carry the waste water round the end of the embankment in the solid ground rather than to have the best possible design of waste weir and bye-wash channel intersecting the line of the embankment. The construction of an open masonry weir and bye-wash channel over or through any portion of an earthen embankment spoils the whole homogeneity of the work by cutting through the puddle wall.

In this case by the adoption of the tunnel for a portion of the length of the bye-wash the necessity of cutting through or in any way interfering with the puddle wall has been obviated.

If an open cut or bye-wash had been adopted in this case it would have been necessary to have altered the method of the puddle wall construction at this end of the embankment—an addition which was found would have added very considerably to the cost thereof.

In conjunction with the bye-wash channel and tunnel

will be constructed the overflow weir or safety valve of the reservoir.

The form and description of overflow adopted for this scheme is not original, but is nevertheless novel. It consists of a circular shaft surmounted by a circular overflow weir. The diameter of the shaft at the weir level is 72 feet, and tapering downwards the shaft is reduced in diameter to 20 feet.

The depth of the shaft, measured from the crest of the weir to the invert of the bye-wash tunnel below, will be 43 feet, but at the bottom of the shaft there will be a sump which it is proposed to carry to a further depth of 6 feet.

This sump will form a water cushion. In arriving at the decision to adopt this form of waste water disposal, the author was influenced by the knowledge which had been obtained as to the rock formation on this side of the valley, and the opportunity it afforded of securing the most permanent structure.

This shaft is entirely cut out of the solid rock, no portion of it being constructed with the exception of the weir on top. This method of disposing of the flood water is but an application of the principle of the upstand pipe in a bath or cistern, and its construction in this instance will form, so far as the author has been able to ascertain, the third within the United Kingdom. The adoption of the design in this case, however, is under more advantageous circumstances, being cut out of the solid rock, whilst those at Blackton and Tynemouth are constructed of masonry. Being entirely of rock, and altogether free from constructional masonry of any and every description, it combines the maximum of strength and durability compatible at the same time with the highest standard of efficiency.

Before finally submitting this form of overflow for adoption, the question of cost, as compared with an open weir and bye-wash, was most carefully considered, and the result, after many alternatives had been thoroughly entered into, was that this would prove the cheapest method of providing for the disposal of the waste water.

Assuming the maximum flood to be dealt with after the completion of the works will be the same as that calculated for during their construction, it was found that a weir 226 feet in length would meet all the requirements and permit the flood to discharge in good time, and thus obviate the risk likely to occur from considerably raising the water level over the entire reservoir. This length of weir will secure that the maximum flood will not rise more than two feet over the level of the crest.

The author has prepared the following table, showing the comparative lengths of several weirs and the proportion they bear per 1,000 acres of their catchment areas:—

STATEMENT SHOWING COMPARATIVE LENGTHS OF WEIRS TO CATCHMENT AREAS.

Reservoir	Catchment Area	Length of Weir	Number of feet of Weir per 1,000 acres of Catchment Area
Talla (Edinburgh) ...	6,180	200	32.3
Font Valley (Tynemouth,	7,400	300	40.5
Burrator (Plymouth) ...	5,360	125	23.3
Baldersdale	10,100	240	23.7
Lunedale	18,900	500	26.4
Roundwood (Old) (Dublin)	13,700	300	22
Roundwood (New) (Dublin)	9,000	226	25

Embankment.—When the necessary provision for diverting the river has been made by constructing the eduction canal tunnel and bye-wash channel, the construction of the main impounding embankment will be proceeded with.

This embankment will be constructed right across the valley, and the reduced level of the roadway on top will be 744.00, or 6 feet above the level of the crest of the overflow or waste weir. The length of the embankment, measured at this level, will be over 2,200 feet, and will stand over 50 feet above the natural surface of the ground at the river level—the maximum depth of water impounded being 44 feet.

The entire area covered by the base of the embankment will be 8a. 0r. 3p., which will be entirely cleared of top soil and all vegetable growth.

The maximum width of the base of the embankment which will be at the river level will be over 290 feet.

The width of the road on top of the embankment will be 21 feet, and a screen or parapet wall 5 feet in height will be built along the up-stream side of this road.

The inner slope of the embankment will be 3 to 1, paved with stone pitching laid on a bed of broken stone. The depth of the pitching varies from 12 inches on a 6-inch bed to 18 inches on a 12-inch bed. The outer slope will be $2\frac{1}{2}$ to 1, which will be soiled and sown with grass seeds.

Puddle Wall and Trench.—The puddle trench will be 2,690 feet long, and will be carried down through the rock until a firm, impervious bed has been reached. The ground overlying the rock varies considerably in depth from 10 feet to 38 feet. In consequence of the water-logged condition of the ground upon the western side of the valley it is proposed, in accordance with Mr.

Mansergh's suggestion, to construct in the excavated rock a concrete shoe with a tongue in which the base of the puddle wall will sit.

The puddle wall will be 6 feet thick on top, and will be carried up 4 feet above the level of the crest of the overflow weir. It will be equal in length with the puddle trench (2,690 feet), and will have a batter on each side of 1 in 8. The maximum width of the puddle wall at the natural surface of the ground at the river level will be 18 feet.

Road Diversions.—There will be two road diversions, as the area now fenced in for the proposed reservoir is traversed at two points by roads. As both of these roads for a certain portion of their lengths will be submerged, it will be necessary that they shall be diverted either in a horizontal or vertical direction.

In the case of the first a new road will be constructed immediately adjoining that of the present road, and in the second instance the existing road will be diverted in a vertical direction—the new road being constructed on top of the existing road.

One of these roads is the main county road leading from Bray to Roundwood and the Seven Churches, and is situated on the western side of the valley. It is proposed at this place to construct a new road on the eastern side of the existing road. The length of the new road will be 900 feet. The existing road can be kept open for traffic during the construction of the new road, which will be a great convenience in drawing materals, and will obviate any dislocation of traffic.

The second is an accommodation or bye-road, and crosses the valley at a point about one and a half miles above the centre line of the proposed main embankment.

The embankment portion of the roadway will be 1,412

feet in length, and will rise 18 feet 6 inches over the level of ground at river.

General Works.—In connection with the scheme it will be necessary to construct boundary walls along a portion of the Mullinaveige and Knockraheen roads, at the junction of the centre line of the embankment with these roads, together with entrance gates and piers.

It is also proposed to erect at the entrance gates on the Mullinaveige Road a steward's or caretaker's lodge.

For the carrying out of the works provision will be made for the housing of the men who will be employed, and the site selected for the erection of the necessary dwellings, very fortunately, is situated without the catchment area of the Vartry. The drainage, therefore, from this site will be disposed of without incurring any risk of the pollution of the streams or watercourses at present draining into the existing reservoir.

The fact that a large number of men will be employed upon the work has necessarily considerably exercised the minds of those responsible, in order that no nuisance should be committed by the men upon the Corporation grounds, and the most stringent regulations have been drafted for the guidance of the contractor. In addition, the contractor will be required to make every provision possible for the convenience of the men. There will also be a destructor provided and erected for the systematic disposal of the sewage, which should obviate all possible risk of pollution of the area.

The following table of the principal features and dimensions of the proposed reservoir at Roundwood has been prepared, and similar information regarding them has been obtained with respect to earthen embankments on the existing reservoir at Roundwood, Talla for Edinburgh, and Font Valley for Tynemouth :—

COMPARISON OF THE PRINCIPAL FEATURES OF THE PROPOSED AND EXISTING RESERVOIRS AT ROUNDWOOD (DUBLIN) WITH TALLA (EDINBURGH) AND FONT VALLEY (TYNEMOUTH).

	ROUNDWOOD (Proposed)	ROUNDWOOD (Existing)	TALLA	FONT VALLEY
Catchment area	9,000 acres	13,700 acres	6,180 acres	7,400 acres
Length of reservoir	2⅛ miles	2½ miles	2½ miles	1¼ miles
Area submerged	303 acres	409 acres	300 acres	87 acres
Maximum depth of water	44 feet	60 feet	80 feet	80 feet
Capacity	gallons 1,259,000,000	gallons 2,400,000,000	gallons 2,800,000,000	gallons 720,000,000
Length of embankment	2,220 feet	1,640 feet	1,050 feet	1,040 feet
Width at top	21 „	28 „	20 „	20 „
Top of embankment over crest of overflow weir ...	6 „	6 „	7 „	6 „
Width of puddle wall at top	6 „	6 „	10 „	6 „
Batter of puddle wall	1 in 8	1 in 12	1 in 8	1 in 12
Top of puddle wall over crest of overflow weir ...	4 feet	5 feet	5 feet	3 feet
Thickness of plugging of eduction tunnel	16 „	39 „	18 „	24 „
Length of Overflow Weir	226 „	300 „	200 „	300 „

Mr. Bergin, in proposing a vote of thanks to the author, said the paper was a very interesting one, and contained a considerable amount of very useful information. The construction of such an embankment was a work of the first magnitude, and he was quite sure that the paper which they had just listened to would prove a valuable addition to the literature of the Institute, especially when accompanied by the excellent drawings and diagrams which had been exhibited that evening. With regard to the flood water discharge, it appeared to him that 15 cubic feet per minute per acre was rather excessive, and he was glad to see Mr. James Dillon present, as he would be able to give them some valuable information on this point gained during his long experience of arterial drainage works carried out all over the country. A flood discharge of 15 feet per minute per acre might occur in small elevated catchments, especially on the west coast of Ireland, but in his opinion it would not be experienced anywhere in Ireland in a catchment of the character and extent of the Vartry.

With reference to the overflow shaft it certainly was of a novel character, having been adopted for only two other works so far, and the design was undoubtedly admirably adapted to the configuration and nature of the ground where it was proposed to construct the shaft.

The form of the eduction tower was also, to his mind, well designed, as it was a great advantage to have easy access to all the valves, which sometimes give so much trouble owing to the difficulty often experienced in getting at them.

With regard to the concrete shoe, this design might suit very well in some places, but he did not consider it an economical one in a locality where there was an unlimited supply of excellent puddle, and where the transit

of materials, such as cement, was so very high. He doubted whether it was worth the additional cost it would entail.

Mr. Butler, in seconding the vote of thanks, said the paper was an excellent one, and he was very pleased to hear it read. He had personally never carried out any waterworks, but possibly that was the reason why he had been selected to second the vote of thanks. One was struck most forcibly by the enterprise of the Corporation of Dublin so many years ago in undertaking this great scheme of waterworks on the Vartry, long before other cities attempted works on a similar scale. Dublin was fortunate in having such water so comparatively near at hand, which compared very favourably with Birmingham, Glasgow and other cities. The water supply of Birmingham had to be carried nearly one hundred miles from near Ryader. Owing to the remote and isolated situation of the Birmingham waterworks one of the first things the Corporation of that city had to do was to build practically a town, the plans for which he had the opportunity of seeing the other day. Dublin had been saved this necessity.

Mr. Bergin had dealt with the technical parts, and all he could say was that the paper was a very good one, being both brief and clear. The author had given them an excellent synopsis in an exceedingly simple manner and in a few words. The drawings were equally clear, and shown in a very admirable manner. They were in great contrast to the illustrations to some papers read, which had not been so well done, on previous occasions. It was a very good idea to have an assistant to use the pointer, as it enabled the author to get through the paper in less time, in a better manner, and without distraction.

He would like the author to give them a little more information about the shoe recommended by Mr. Mansergh to be put at the base of the puddle wall. He was not quite clear as to why Mr. Bergin disapproved of it, unless it was that it was not homogeneous with the puddle. Perhaps the author could enlighten them.

Mr. Dillon said he was very glad to have heard the paper read. A good many years ago he happened to be chairman of the Sanitary Committee of Kingstown District when they got notice from the Dublin Corporation that if rain did not fall they would unfortunately be obliged to cut off the whole Vartry supply to Kingstown District. He realised what that meant, and could not understand how such a state of affairs should have come about. So he and the other members of the committee went out to the waterworks to satisfy themselves that there was no water in the reservoir. He should have said that there was an exceptional dry summer that year. However, they found the Vartry reservoir so dry that they could walk across its bed. He was, therefore, pleased to hear of any proposed scheme that would place the Dublin district in such a position that the district would not be in danger of being left without water.

With reference to the flood discharges due to a fall of 15 cubic feet per acre in twenty-four hours, of course it was understood that such a discharge would be greatly in excess of what was expected or had taken place in this country generally. In reservoirs at great elevations they might be affected by the south-east winds highly surcharged with water, and the flood discharge increased accordingly beyond the usual volume; but if they ever got 15 inches it would be very exceptional. He thought they should have a good supply, and he hoped when the works

were finished that they would prove as substantial as those which were now many years in use.

Mr. J. H. Ryan asked the author were there any catchment drains round the proposed reservoir. The catchment area was very large, and he took it that the whole catchment area drained into the proposed reservoir. He noticed there were several farms in the catchment area, and there certainly would be some contamination arising therefrom. In the Belfast waterworks system they had gone to an immense expense in clearing all the farms from the catchment area—in fact, the catchment area had been turned into a prairie. It had been found that the water was contaminated to a certain extent by these farms, and he would like to know if any provision was made for the purpose of intercepting any contamination from the proposed reservoir at Roundwood.

Mr. J. T. Jackson said that an additional advantage conferred by the proposed reservoir would be the greater security against the effects of any accidental bacterial contamination. The longer storage period would secure the most thorough purification of the water through the agency of the dissolved oxygen.

Mr. George Moore said he desired to ask one or two questions. He would have liked to have heard something about the experience gained by the sinking of the trial pits, as very little had been said on that subject. The author did not say what was the nature of the soil, or if he came across springs of any great magnitude. He (Mr. Moore) had had some experience of the nature of the ground in that district, and frequently found it very treacherous. Owing to the water-logged description of the soil he anticipated great difficulties as to springs being discovered when sinking the tongue in the rock under the embankment for the puddle core to go into. He would

like to know from the author, in the event of coming across such springs, which would probably be of great magnitude, what method he proposed to adopt to deal with such difficulties. The author referred to different classes of rock existing, and he (Mr. Moore) would like to know how many classes he had discovered in the immediate vicinity of the proposed embankment. He thought they were likely to get different sorts here—some would possibly be soft and porous, and others hard. He would like to know in the event of the former what provisions the author had made. If they were so fortunate as to get the latter it would, of course, be all right.

THE PRESIDENT (Mr. J. H. Moore) remembered that when he was a young man at college these works were just finished. It was about that time that the Sheffield dam burst, and everyone was filled with the idea of the great danger there was of something similar happening at Roundwood. The residents along the river below the works claimed and were paid compensation for the damage that *might* accrue if the Vartry dam broke down. The dam was still there, and had not broken down yet. If this new dam did burst it would carry away the first, and things would be in a bad way. However, he thought there was very little danger of either of these dams bursting. Mr. Dillon had referred to the year 1893, when they had an exceptionally dry season. He had gone to see the reservoir, and it was practically dry, and was a most extraordinary sight. It cost the Corporation a considerable sum of money, for they had to lay pipes along the Royal Canal from near Ashtown to bring water to the city. The rain came, however, before this supply was required, and no such scarcity had occurred since. Still, what had happened might happen again, and it was necessary to be prepared for all emergencies. With

regard to the provision for storm floods, it might seem excessive, but it was scarcely fair to compare the discharge of floods in the lowlands of Dublin and Meath with what might occur up among the Wicklow Mountains. Exception had been taken to the unusual method of forming the overflow by what was in fact a large standpipe, but as it appeared that both the outlet and vertical shaft were to be formed in solid rock with only a mason-work rim at top, and that in this way the overflow would not interfere in any way with the dam, the proposed arrangement seemed to him well suited to the circumstances of the locality.

Mr. O'Sullivan thanked the members for their appreciation of his efforts, and said that if he had succeeded in stimulating an interest in his paper it was largely due to the advantage of having had the use of the lantern to place before them the plans. For this he said he was glad to have the opportunity of saying the entire credit was due to the Hon. Sec. (Professor Lilly). He it was in the first instance who suggested the use of the lantern, and he subsequently went to a great deal of trouble in the preparation of the various slides which had been shown. Were it not for the assistance he had received from Professor Lilly, who had taken the matter up most warmly from the time he promised the paper, he would have been most diffident in appearing before them to-night.

Replying to the points which had been raised about the paper, he said in making the trial holes it was found that the rock underlying the site of the embankment was Cambrian slate, and as a result of an examination of all the trial holes he had no reason to presume the existence of any geological fault.

The concrete tongue and shoe for the puddle wall was

recommended by Mr. Mansergh as a means for dealing with a difficulty that might arise in the construction of the puddle wall. Portion of the ground on the western side of the valley was found to be very much water-logged, and it was feared large quantities of the subsoil water would find its way into the rock excavation during the progress of the works and wash away the puddle when it would be placed in position at the bottom of the trench. It is proposed to place cast-iron pipes in the bottom of the rock trench with connections for small pipes which will be laid on the upper surface of the rock. These pipes will be connected with a sump in the lowest part of the valley, and from thence the water will be pumped into a filter bed. The puddle wall will sit in the shoe, which will extend half-way across the valley.

With regard to fissures or defects in the rock, they had provided for this in the specification, as the contractor must excavate to such a depth as will effectually cut off all seams, springs, or veins of soft material, but he thought very little difficulty of that kind would be likely to occur.

There are no catchment drains round the existing reservoir, except for a portion along the southern side, and it is not proposed to construct them round the new reservoir; a short length of drain may be constructed where necessary. There are farms on the catchment area, but there is no greater danger now of pollution than there has been for years past, as these farms have existed all the time. The progress of the new works will not of itself increase the danger from this source, and the Corporation do not intend to purchase the ground of the catchment area.

[6th May, 1908.]

ANNUAL GENERAL MEETING.

Mr. J. H. Moore, President, in the Chair.

ELECTION OF OFFICERS AND COUNCIL.

The President announced that the Council had decided that, as an omission to comply with Clause 1 of Section V. of the Bye-laws had occurred, the elections would be postponed, and the present meeting adjourned in order to take the advice of counsel on the point raised.

[6th May, 1908.]

ORDINARY GENERAL MEETING.

MR. J. H. MOORE, President, in the Chair.

The following Candidates were balloted for and duly elected:—

C. J. DUNN, as an Associate Member.

J. T. MURPHY, as an Associate Member.

THE PROTECTION OF ENGINEERING STRUCTURES FROM LIGHTNING.

By J. T. JACKSON, Member.

THE ordinary phenomena of atmospheric electricity are amongst the least obvious in nature. There is but little to call attention to them, and their manifestations are only to be detected by the use of delicate instruments. That the electrical potential of the air rises as we ascend above the surface of the earth at the rate of about 100 volts per yard of ascent; that the conducting layer of rarefied air which lies twenty or thirty miles above the denser body of the lower atmosphere is at a potential of perhaps a million volts higher than that of the earth; that there is a current of about 300 amperes flowing quietly from the air to the earth; these are facts—but facts which might very easily be overlooked. But when the potential of any portion of the upper air rises, say to 5,000 million volts, while its distance from the earth diminishes to one mile, then the conditions of discharge are wholly changed, the electric stress on the air reaches the limit of about 1 lb. per square foot, disruption occurs, and a current of, say, 3,000 amperes, passing for $\frac{1}{40000}$ of a second transmits one-sixteenth of a coulomb of electricity and liberates 50,000

foot tons, or 150,000 British thermal units of energy, chiefly in the form of heat.* This energy it is that heats the air in the path of the discharge to incandescence, that shatters, fuses, and even volatilises badly-conducting solid bodies through which the discharge passes, and that, in brief, produces the well-known alarming and destructive effects of lightning.

With regard to the origin of atmospheric electricity, and, consequently, the source of the energy which is manifested in the thunderstorm, various theories have been proposed, and no theory appears to have been conclusively verified. Pouillet supposed it to be due to evaporation, vapour rising from the sea being positively electrified. Lodge holds that it is the result of wind friction, while J. J. Thomson considers that it may be the result of condensation, water vapour in the upper air condensing on negative electrons as nuclei, carrying them down to earth in rain drops, and so as it were sweeping the negative electricity from the air, leaving it positively electrified.

But whatever theory be adopted the facts remain the same. We know that the upper regions of the atmosphere are at a much higher electric potential than the earth; that occasionally masses of condensing vapour (clouds) have their potentials very much raised, and come within sparking distance of the earth or of one another; that this enormous electric spark is capable of doing a great deal of damage to life and property; and lastly, what is most important from our present point of view, that it is possible, by a suitably arranged system of metallic conductors, to secure for a given structure any desired degree of protection from injury by lightning.

* The above figures are, of course, only very roughly approximate; they give, however, an idea of the order of magnitude of the quantities involved.

The obvious methods, then, of protecting a structure from the destructive effects of lightning are:—

1. To prevent the discharge if possible, and if this cannot be done,

2. To divert the electric current by offering it an alternative and easier path to earth.

The lightning conductor aims at effecting both these types of protection—the first by virtue of its pointed terminals which permit of a slow or "silent" discharge that under certain circumstances may so far relieve the electric stress in the air above as to stave off the flash or disruptive discharge, and the second by offering to the disruptive discharge a path to earth which is easier and more direct than that offered by any portion of the structure to be protected.

Before considering in detail the essentials of a satisfactory system of lightning protection, it is necessary to examine the nature of the lightning discharge a little more particularly. The first point to notice is that while the disruptive discharge can only take place through air which has been previously strained to the point of rupture this strain may have occurred—

(A) Gradually, as where a highly-charged cloud approaches a building until the distance between them is so small that discharge occurs.

(B) Suddenly, as where a cloud the lower side of which is uncharged, lies over a building, and an overlying or adjacent highly-charged cloud discharges to the first cloud, to another cloud, or to earth, suddenly transferring a charge to the lower portion of the cloud over the building.*

* This distinction between lightning discharges was first pointed out by Sir Oliver Lodge, who distinguishes the first or gradually prepared discharge as the "A" type of flash, and the second or sudden kind as the "B" type.

Now, it is evident that sharp points on a conductor may be extremely useful with the gradual or A type of electric strain, both by tending to avert the flash* and by supplying to it, if it does occur, a stream of air at nearly earth potential which will lead it to the conductor. With the sudden or B type of strain it is equally clear that points are useless; there is no time for silent discharge, there is no negatively electrified air streaming from the points to direct the flash at the conductor. The conductor, in fact, must be put in the way of the flash in order to be an absolute protection, and so it comes about that to completely protect a building from B flashes as well as from A a large number of conductors are necessary, and, indeed, that absolute protection is only to be had by completely enclosing the building in a network or cage of conductors.

It has been stated that the function of a lightning conductor is to dissipate the energy of the discharge, that consequently a conductor of moderately high resistance is better than one of perfect conductivity, which would deal with the energy in too sudden and rapid a manner, and so produces a result equivalent to an explosion.† This appears to me to be a somewhat mistaken view. The function of the conductor is, I would submit, not to dissipate energy itself, but to alter the place of dissipation from the protected building to the air above. The thunderclap may be a little louder and the flash a little brighter with a thick copper conductor than with a fine iron one; but in either case the energy absorbed by the conductor is probably but a small fraction of the total energy of the discharge.

Another important point to notice about the lightning

* Some recent American statistics are said to show that the effects of points in averting the lightning flash is small, only about six per cent. of the flashes being stopped by the silent discharge.

† See preface to Report of Lightning Research Committee, by Sir Oliver Lodge.

discharge is its oscillatory character. The quantity of energy stored in the strained air is very great, and it is not usually all dissipated in the first discharge, so that the electric charge as it were overshoots the mark, too much leaves the cloud. This excess again surges back from the earth to the cloud, again charges the cloud, and so the flashing to and fro between cloud and earth goes on for perhaps a dozen oscillations until the energy of the flash is completely expended. The path which the flash will select will then be that which offers least impedence to the passage of an alternating current of extremely high frequency (say 100,000 alternations per second). It will be a path in which one unit of self-induction offers as much obstruction as 600,000 units of resistance. In brief, it will be as far as possible a *direct* path. But again, two parallel or diverging paths have less self-induction than one, and so there is a very marked tendency for lightning to run to earth by several paths. Furthermore, the violent electric surges in the path of the main discharge induce surges in all neighbouring conducting bodies (exactly as the surges in the transmitting aerial of a wireless telegraphic installation induce other surges in the receiving aerial), and these induced discharges, while possessing comparatively small energy, may still be extremely dangerous either directly to life or indirectly to both life and property, as when they cause fire by igniting gas or otherwise, explode gunpowder in magazines, &c., &c. From these considerations it is obvious that to secure immunity from side flash and induced sparking all large masses of metal, both outside and inside a building, must be interconnected and also earthed, either through the conductor or separately.

The following rules and recommendations for the protection of buildings by lightning conductors embody the

practical results of these peculiar characteristics of the lightning discharge* :—

1. Two lightning rods, one on each side, should extend from the top of a tower, spire, or high chimney by the most direct course to earth.

2. Horizontal conductors connected to all the vertical rods should be carried (*a*) along the ridge, round the roof, round the chimney top, &c.; (*b*) round the building or at or near the ground line.

3. Points should project from these upper horizontal conductors at frequent intervals.

4. All roof metals should be connected to the upper horizontal conductors.

5. All large masses of metals in the interior should be earthed, either directly or through the lower horizontal conductor.

6. The point of the upper terminal should not be sharp; but a little below it three or more sharp copper points should project from a ring attached to the terminal.

7. Chimneys and orifices from which steam or heated air escape should receive special attention. Factory chimneys should have a copper band running round the top and a series of stout copper points, about one foot long, projecting at intervals of about three feet either from this band or from a copper bar bent archwise over the chimney.

8. The rod should not be insulated, but should be attached by holdfasts of the same metal as the rod.

9. All sharp curves, angles, and bends should be avoided. The rods should be brought to earth by the most direct course possible.

10. It is better to put rods on the sides of a building that are most exposed to rain.

* Mainly taken from the Reports of the Lightning Rod Conference (1882) and the Lightning Research Committee (1905).

11. The material of the conductor may be either copper or iron,* in the form of tape, rope, or rod. For main conductors copper weighing at least six ounces per foot run, or iron weighing $2\frac{1}{4}$ lbs. should be used. Subsidiary conductors may be considerably lighter.

12. Copper need not be painted, but iron should be galvanised and painted.

13. In manufacturing districts, near the sea, or where liable to be exposed to the action of corrosive vapours, the use of iron is inexpedient.*

14. It is absolutely essential that the lower end of the conductor shall be effectively earthed by giving it a sufficient area of contact (about 18 square feet) with permanently damp soil. This may be effected—

(*a*) By soldering† the end of the conductor to a plate of the same metal, size 3ft. by 3ft., and at least one-sixteenth inch thick (the soldered joint to be well protected from corrosion), or by folding backwards and forwards in gridiron form a length of the conductor sufficient to expose the necessary surface area and burying the plate or grid surrounded by charcoal or broken-up ends of arc light rods at a depth sufficient to secure permanently moist earth.

(*b*) By laying a long length of the conductor (sufficient to expose 18 square feet surface) in a trench and covering with charcoal, cinders, or coke before filling in.

(*c*) By the use of a "tubular earth," which consists of

* Aluminium, owing to its high conductivity, high specific heat and great permanence, ought to be an excellent material for conductors.

† Soldering is recommended by the Lightning Rod Conference. The War Department practice is to rivet the conductor ($1'' \times \frac{1}{8}''$ copper tape) to the earth plate, while the Irish Lights practice is to separate the strands of copper tape strand, $1\frac{1}{2}''$ copper rope conductor, and lace the strands through a number of holes in the earth plate. Both these methods avoid the use of solder, and so the joints are less liable to injury by electrolytic action. There is, of course, a sacrifice of conductivity, but the greater permanence probably justifies it.

a strong perforated steel tube, about two inches diameter, furnished with a sharp spike. The tube is driven down by a hammer or mallet, and lengths are added till permanently moist ground is reached. The conductor is threaded through the tube and packed round with granulated charcoal.

(*d*) By joining to a gas or water *main* (not to a lead pipe).

15. Arrangements should be made to lead a supply of rain water into the pit, trench, or tube forming the earth in (*a*), (*b*), or (*c*), so as to ensure a thoroughly moist earth.

16. It is a good plan to make the conductor bifurcate below the ground and to use two of the above types of earth.

17. In the case of buildings near the sea, where the conductor can conveniently be led to the sea or into shingle or sand below sea level, an area of five or six square feet of earth plate is sufficient.

The main consideration in the matter of lightning protection is, after all, one of expense. It is, in fact, a question of insurance, and the proper amount of protection to be afforded to a given structure can only be decided by considering the following points:—

1. The liability of the structure to lightning stroke.

2. The probable extent of the damage if struck in the unprotected state.

3. The probable extent to which this damage would be diminished by various systems of protection.

4. The costs of these systems of protection.

Structures peculiarly liable to be struck by lightning are those erected on high ground or on wet ground, and which tower high above surrounding objects, such as churches, factory chimneys, lofty stores, lighthouses, ships, &c.; also metallic structures which extend continuously for a

great distance horizontally, as overhead cables and wires, telegraph lines, rails, long lines of iron fence, &c.

The extent of the damage if a structure is struck by lightning will depend on the shape, material, cost, and use of the structure. Thus, lofty erections are more liable to suffer greater injury than lower ones, as the path of the discharge to earth is longer, and injury to the lower portions may be caused by the fall of the upper portions. Iron structures are practically safe from direct injury, but it is important to consider what will happen when the discharge leaves the structure, as much harm may be done then. Thus, an iron tower or bridge may have its foundations seriously shaken and disturbed. The use to which the structure is put is also important. For instance, a powder magazine or powder mill can hardly be too well protected—the consequences of even the smallest side-flash may be so serious. Again, the head-gear of a colliery should be earthed, as explosions of fire-damp have occurred through lightning flashes being conducted down the winding-rope.

With the increasing use of ferro-concrete for engineering and architectural purposes the question of the possible effects of lightning on structures of this material becomes important. It is evident that so long as there is good metallic contact between the steel bars in the outer portions of the structure no injury can occur save where the discharge enters and leaves the steelwork. The injury at the point of entry would probably be comparatively small and easily repaired; but at the point of exit the foundations might be injured, and so it would appear in general that while no overground external conductors would be necessary on such structures it would in most cases be advisable to thoroughly earth the steelwork.

The question of affording partial protection at a very

small cost is one which has received far too little attention. The dictum that a faulty conductor is worse than useless—a statement which has no foundation either in theory or experience—is probably to a great extent responsible for this. It appears to be a natural consequence of the equally erroneous statement that lightning conductors *attract* lightning—*i.e.*, that buildings fitted with conductors are more likely to be struck than had they not been so fitted (see footnote). There is no doubt but that a large degree of protection may be afforded to a building by a system of conductors in which the vertical rods are galvanised iron wire no thicker than ordinary telegraph wire,* and the upper horizontal connections are simply ordinary barbed fencing-wire. If such conductors are destroyed by a flash they will have served their purpose *before* their destruction.

Mr. M. Ruddle said their thanks were due to the author for his paper and the very concise form in which he had given them so much information on the subject. Personally he had not very much to do with the subject in recent years, but some twenty-five years ago he had to consider the question of preventing damage to buildings from lightning, and as far as he could see there was very little change in the methods adopted then, and there had been very few improvements in the lapse of years. He noticed throughout the paper that the author adopted the popular view that buildings are "struck" by lightning. In some cases that might be so, but he thought that the result of investigations had shown that in the majority of instances the damage occurred from the disruptive discharges from the ground to the clouds. When the phenomenon does occur it is generally very difficult to

* See Lodge's Lightning Conductors and Lightning Guards, page 209.

investigate it on account of the damage which generally occurred on the path of the discharge, destroying the evidence of the previous facts of the installation, and as a rule people were not called in to inquire into the cause of the accident until some time after it happened, when very often it was too late to hold a proper investigation. The author, in a very off-hand way, had spoken of the potential of the upper air rising to 5,000 million volts. This was rather vague, but he did not consider it was of much importance, and the main point to consider was how far protection could be afforded to buildings, &c. The difficulty in dealing with most cases was to decide whether the damage was caused by the discharge from the earth or from the clouds. He thought from the fact of the form of lightning conductors which were in use, and which were thought to give the best protection from damages, showed that in the majority of instances the discharge was from the ground. Lightning conductors generally terminate in one or two points, usually made as sharp as possible, and by these the silent discharge of any accumulation in the ground is achieved. So far as he had been able to gather, if the discharge of any potential energy from a cloud earthward took place no lightning conductor so-called could protect that building, because the amount of energy in the flash would be too great for any ordinary conductor that is in general use to carry off.

With reference to iron buildings he had known iron buildings that had been struck and had seen an iron chimney that had been cut in two as if it had been sawn. In this case, so far as could be ascertained, the foundation piles ended in damp soil and were an effective earth.

It was extremely difficult to formulate or reproduce the actual conditions which took place, and until that could

be done it was only by experimental installations on buildings, and waiting, perhaps, for years to get the results, that they could come to any approximation of the best way to protect buildings.

The author had said that American statistics were said to show that the effects of points in averting the lightning flash was small, only about 6 per cent. of the flashes being stopped by the silent discharge. Well, American statistics was a very wide term. America was a vast country, where there was a very large variation of subsoil. In some places they would find large metallic deposits and in other places dry sand and clay. When they wanted to consider the question of protection these things had to be taken into account.

It was found in a general experimental way that the only method of effecting a silent discharge was to have a large number of fine points. With reference to what the author had said about the side flash and its effect on large masses of metal inside and outside a building he had known cases where large masses of machinery inside a building were not connected to the lightning conductor, though only separated by a brick wall eighteen inches thick, and no damage resulted, though the conductor was destroyed, and he had known other cases in which large masses of machinery inside a building were earthed with strips of copper of one inch by one-eighth inch section and damage resulted. It was very difficult to say which was the most effective plan.

The recommendations of the Lightning Research Committee were very elaborate. He remembered some years ago hearing a learned professor in a very large college giving an elaborate lecture on the subject, and one of his strong points was that the lightning conductors should not be insulated. After the lecture, when leaving the

building, he noticed, in close proximity to the room where they had been, that there was a lightning conductor which was very carefully insulated and carried by the most devious paths along the moulding of the brickwork. He suggested that this was hardly in keeping with the previous lecture, but the professor did not attempt to defend it.

Many kinds of lightning conductors were used on various buildings and chimneys, but he thought the most suitable was copper tape of one inch by one-eighth inch or one and a half inch by one-fourth inch. It was least affected by the corrosion which was continually going on.

With regard to the terminal plate in the ground and any joints that were necessary to make to the conductor, he thought it was most essential that the conductor should be well riveted to the earth-plate and, if possible, brazed, so as to have a clean contact. Soldered joints had been suggested, but these were likely to set up a galvanic action; however, he had tried them on various terminals and nothing serious occurred. It was also very easy to protect these joints by coating the junction with pitch.

He thought it would not be good practice to join rope conductors in the manner mentioned by the author. That was to separate the strands and join them singly to the plate. If they did so, the amount of cross-section of the strands was so small that there would be greater danger of them corroding away.

With regard to what the author had said about the protection of ferro-concrete buildings, he did not agree with his statement that "It was evident that so long as there was good metallic contact between the steel bars in the outer portions of the structure no injury can occur save where the discharge enters and leaves the steel

work." He considered no building would be safe if it depended on this without providing a suitable conductor; but whether they should also join the steel frame to the conductor or not was an open question. He thought they were not going to get protection from discharge, but they were going to have the best conditions of disposing of it through the conductors from these points.

With reference to the suggestion that some degree of safety might be afforded to a building by the use of several galvanised iron wires, he thought that they would not last very long or be very safe. He was not in favour of iron because of the difficulty of making good joints in the various sections of conductor and earth-plate.

Mr. P. Sheardown said the paper was an interesting one, but the author had made statements which could not be put to practical test for verification on account of the danger attending experiments to ascertain the differences that existed in the upper and lower stratums of the air.

The paper was a mixture of theory and practice—the results in practice not always bearing out the correctness of the theory. The author had told them that the amount of electricity in the average lightning discharge was about one-sixteenth of a coulomb. It might be interesting to know that in a 25 candle-power incandescent lamp the amount of current passing on a 100 volt circuit was about one ampere or one coulomb per second; therefore, the electricity passing in the lightning discharge was about one-sixteenth of the amount of electricity that passed through a 25 candle-power electric lamp per second when working on 100 volts; but the electrical power was the product of the flow of current multiplied by the difference of potential or pressure which caused it to flow. The amount of electricity mentioned by the author was very small, but it was stated that the pressure under

which it worked was somewhere about 5,000 million volts. This was a much larger pressure, of course, than had ever been obtained in practical working. The highest pressure he had heard of was in California, where it was stated they had attained a pressure of something like 100,000 volts.

He thought the author might have told them more about the results that had been obtained in practice with lightning conductors. With regard to lightning conductors he thought that they were required to work under two quite separate sets of conditions. Lightning arresters might discharge the electricity from the upper stratus of the air to the earth, and so tend to equalise the potential by passing a continuous stream of current and preventing the excessive rise of potential of the clouds immediately above the building to be protected, or, in other words, might be useful in obviating the flash of lightning taking place, and undoubtedly they were very useful under these conditions. The second function they were expected to perform was to safely carry to earth the lightning flash which was discharged towards the building, and it is problematic as to what the efficiency of the ordinary lightning conductor was under these conditions. In designing a lightning conductor for the first set of conditions one of the most essential features would be to have the lowest possible conductivity; but in the case of a lightning discharge this has been proved to take place in the form of a rapidly-oscillating current, and, under these conditions, it was more important to keep the self-induction as low as possible—the resistance of the path being of little consequence.

The author had suggested various forms in which the lightning conductor could be made, but theoretically the speaker thought with regard to lightning discharges

the proper form for the conductor to take would be that of a tube, owing to the fact that with the rapidly-oscillating current the internal part of a self-conducting rod seemed to be of little use for the passage of the electric current.

Mr. W. Tatlow said the author had told them some very interesting things in his paper. It was a pity they were unable to tap the very large quantity of electrical energy that was thirty miles up in the air. If they were able to get some of this energy they might be able to turn it to some useful purpose. But if they did succeed in tapping it they might possibly change the climatic conditions of the country round about them.

He thought there should be some standard set of rules recognised for the time being as the best for lightning conductors. At one time he erected a lightning conductor for a gentleman, who was very much annoyed because insulators were not used, and he was unable to refer him to any set of rules to decide the matter.

He thought that conductors should be occasionally inspected. He did not agree with what the author said about bad conductors not being useless. He considered they might be very much worse than useless. He remembered a case where a conductor led into the sea. It was protecting a very important building. He happened to observe the terminal at low water and found it had been corroded away at the lower part, and did not reach the water at low tide.

He had difficulty in believing the generally accepted theory that a lightning discharge was of the nature of a high-frequency oscillation, such as is used in wireless telegraphy, as the resistance within the cloud, through the mass of which the charge is distributed, must be very great, a thunder-cloud being quite different from an

ordinary charged metallic conductor in this respect. He was more inclined to think a flash might be composed of a rapid succession of uni-directional discharges following the same path.

With regard to the earthing of a lightning conductor, it, no doubt, was a very important matter. Telegraphic engineers working in the West of Ireland found it hard to get good earths in some parts on account of the high resistance of the limestone. He had heard that the area of the plate was not the most important matter with regard to earthing in the case of wireless telegraphy. It was a large amount of edge that was preferred. For this reason strips were used instead of plate, because by that means a greater amount of edge was obtained.

Electrical engineers had to deal with another matter in the protection of overhead lines, and for this purpose had to use arresters which would stop the working current from continuing to flow to earth after the lightning discharge was disposed of. He would like the author to explain why structures on wet ground were more liable to be struck than those on dry ground.

He thought that lightning discharges often struck conductors and went to the earth without doing any very serious damage. He was quite sure a great many chimneys in exposed places were frequently struck, and the chimneys were there to the present day. He could not help thinking that chimneys two hundred or three hundred feet in height were often struck and not seriously affected, though according to Mr. Ruddle's theory they would have been destroyed.

Mr. L. J. Kettle said lightning was a subject which possessed attractions of one kind or another for the average citizen, whether he were an engineer or not. The question of lightning conductors and of protection against

damage by lightning had not, however, as yet succeeded in arousing any undue enthusiasm amongst architectural engineers in this country. Most architects seemed to think that a church steeple or a factory chimney might be the better for a strip of copper run up it, but that it would be sheer waste of good material to fix these copper ornaments on any ordinary structure. There was considerable justification for this attitude of mind. The insurance companies did not care fourpence whether a house had lightning conductors or not. If they offered any reductions in the premium rates when conductors were fitted the question would be immediately and generally taken up, for it would then be placed on an obviously sound financial basis instead of the present interesting, if somewhat nebulous, scientific one. The insurance companies, not being generally of a philanthropic turn of mind, had presumably good grounds for their attitude. They had apparently found either that damage by lightning in these countries is so rare as to be practically negligible, or that lightning conductors did not form an adequate protection.

In this connection he would be glad if Mr. Jackson would give them some statistical justification for the use of lightning conductors in this country. The Lightning Research Committee had published a record of instances of lightning strokes in Ireland and Great Britain. If he recollected rightly, the lightning was fairly impartial in its selection of victims, and did not discriminate much in favour of protected structures—in fact, the unprotected structures seemed to have had rather the better of it. Mr. Jackson said American experience had shown that the silent discharge action of lightning conductors formed practically no protection against the "A" flash, and, of course, a lightning conductor was no safeguard against

the "B" flash. This was borne out by Continental experience, so that the only advantage of lightning conductors was that the lightning—when it had struck—was led to earth without doing so much damage as it otherwise might. This might be a considerable consideration where lightning strokes were common.

When fixing a conductor one could not do much better than follow Mr. Jackson's advice. Mr. Jackson had suggested aluminium as a metal suitable for lightning conductors. This metal had several properties which would render it useful for the purpose, but considerable difficulty would be experienced in making efficient joints between the numerous wires. A satisfactory solder for aluminium had yet to be found and other methods of jointing, such as electric welding, would prove rather expensive.

With regard to the size of the strip employed for lightning conductors, Mr. Jackson was apparently under a misapprehension as to why Lodge and the Lightning Research Committee advised the use of conductors of a comparatively small cross-sectional area. With a lightning discharge the ohmic resistance of the conductor counted for very little, and, therefore, the cross-sectional area was of small moment. The choking effect, due to inductance, even in a straight wire, was, on the other hand, very great at the high-frequency of a lightning discharge. This choking effect tended to make the discharge side-flash instead of following the conductor. The greater the cross-sectional area of the conductor the greater was the tendency to side-flash and the greater the possibility of damage to the structure. The Lightning Research Committee stated in their report that—"The conductivity of the conductor is absolutely unimportant except that high conductivity increases the surges and side-flashes, and, therefore, is positively objectionable."

Mr. Jackson had included overhead transmission lines in his list of engineering structures. The protection of such lines was a very different subject from the protection of ordinary buildings, and the lightning conductors discussed in the paper would not be at all applicable. The subject could not be adequately treated in a discussion on lightning conductors. Suffice it to say that the object was not at all so much the protection of the transmission lines as the protection of the electrical apparatus connected to them.

A general conclusion that could be drawn from all investigations on the subject of lightning conductors was that no system of conductors could avert a lightning stroke, and that the only function served by the conductor was to occasionally lessen the damage. Lightning discharges were, however, so uncertain and freakish in their action that very often the conductor did not even serve this function. After all, there seemed to be a good deal in favour of the view of the people who considered that praying and the ringing of bells was a much more efficient safeguard against lightning than the most elaborate and scientific arrangement of conductors. In the matter of praying it might, however, be well to exercise a certain wise discretion if they were to judge from a story that came to them—it was hardly necessary to say—from America. It appeared that in a town in Pennsylvania the erection of a brewery was started notwithstanding the vigorous protests of a local pastor. Having exhausted all other methods of opposition and obstruction to no purpose, the clergyman waited until the building was nearing completion, and then offered public prayers that the brewery might be struck by lightning. Two days later the brewery was struck by lightning and demolished. The owner promptly took an action for damages against

the clergyman, but he regretted to state that a jury of his fellow-citizens showed by their verdict that they had a lamentable lack of confidence in the efficacy of the reverend gentleman's prayers.

Mr. G. Marshall Harris said he agreed with Mr. Ruddle that no conductor put upon a building will entirely protect it against a direct lightning stroke. It did not matter whether it was made of copper or iron. He believed that when the lightning discharge occurred that owing to its enormously high potential it broke through everything opposed to its direct path, and owing to its extremely high periodicity and consequent high inductive effect it could not be relied upon to travel over even short, straight lengths of wire.

Mr. Ruddle had referred to buildings having apparently been struck from the ground. He would rather think that buildings showing these symptoms had been damaged not by the main discharge but by its after effects. When the clouds, or any great portion of them, became charged with electricity of one particular sign such a charge induced a similar one, but of opposite sign, wherever it could do so, and when the conditions were such that the most convenient place was upon a portion of the earth, that portion, including the buildings and the people and animals standing upon it, got filled with this induced charge, which gradually heaped up until a discharge, or, he would prefer to say, an interchange, was effected, because he believed that electricity passed both ways until matters were equalised.

When this interchange was effected in one stroke all the attraction, or whatever it might be, that had heaped up the induced charge, and held it, was suddenly removed, and the body that was filled with it then took up the position in respect to the earth that the cloud had

formerly held. Assuming such a state of affairs, it was easy to explain damage to buildings and people, &c., that have been injured apparently from the ground—if we assume that at the instant of the interchange from above, their contact with the earth was electrically a poor one.

Viewed in this way all Mr. Jackson's recommendations appeared to be the best, because the aim is to keep the building in good contact with the earth and not poorly insulated.

Mr. M. Purcell said, with regard to the question of the earth discharge he remembered a case that occurred in Wigan a few years ago, when there was a heavy thunder-cloud; there was no discharge from the clouds, but there was one from the earth which wrecked the cellar portion of a house and injured some of the people in it. A brother of his, who was in charge of some large engineering works in California, and had some very big installations under his care, told him that he had some very large quantities of naked wires, with arresters all along the system. With regard to the structures out there some of them were made entirely of iron, and they made the earth connection from the building to a running stream where it was possible, and found the results very satisfactory. Where no streams were adjacent to the structures they planted trees (pines for choice) within a radius of 30 yards of the buildings. These trees took the direct discharge from the thunder-clouds passing over them.

The President (Mr. J. H. Moore) said that on reading the paper it appeared to him that very little more seemed to be known about lightning now than was given in the text-books of forty years ago, when he was in college. The figures the author had given them as to the quantity and tension of the electricity in a discharge did not

appear to be of much practical utility, and some explanation was wanted as to how they were arrived at. It was very rarely that anyone was killed by lightning in Ireland, though about two years ago several head of cattle were killed near Duleek—probably by the return shock. A few years ago he had put up a conductor on St. George's steeple, which had not been provided with one before, because, after examination, he had come to the conclusion that the spire had been struck by lightning. The conductor was a strip of copper, and had been brought down inside the building to damp earth in the cellars. For this he had been severely criticised, but no damage had been done by lightning since. He thought such an array of conductors as was recommended in the paper could hardly be necessary, and that with conductors as usually put up they were practically safe in this country from danger by lightning.

Mr. Jackson, in reply, said, with regard to what Mr. Ruddle had said about the direction of the lightning discharge being upward, of course it depended on how we defined or determined the direction of the discharge. Certainly the displacement of matter due to the electric discharge always occurred upwards and outwards, because it was less resisted in these directions. As to whether the disruption usually began at the earth end or cloud end of a flash he would not like to express an opinion, but in any case the break down was practically instantaneous over the whole path of the flash. Sometimes a flash *appeared* to travel from earth to sky, sometimes the other way, but this was an optical delusion due to the fact that some portions of the retina of the eye were more sensitive than others. But adopting the conventional view, that the direction of the discharge is from the place of high (or positive) potential to the place of low (or negative) potential, he thought that in the great majority of cases the

direction of the initial discharge was from the cloud downwards.

With reference to Mr. Sheardown's observation, that the theoretically correct form for a lightning conductor was a tube, there are considerations of architectural effect (on account of greater size), of flexibility, and of cost, all in favour of the use of solid conductors, while the central part of the rod, although its conducting power was of no value, still served a very useful purpose in serving to increase the heat capacity of the conductor, and so prevent fusion.

Regarding Mr. Tatlow's suggestion, that the resistance within a thunder-cloud might be so great as to prevent the possibility of an oscillatory discharge, he thought that the resistance in the path of the initial discharge was so much diminished by the effects of the passage of that discharge that oscillation was possible in the majority of cases. Probably the reason why structures on wet ground were more liable to be struck by lightning than those on dry ground * was that the sudden surge of electricity in the ground, which occurred consequent on an A flash and preparatory to a B flash, passed more readily through wet ground, and so B flashes occurred more frequently there.

With regard to the need for a standard set of rules, the rules, as arranged by the Lightning Rod Conference of 1882, and revised by the Lightning Research Committee in 1905 (*see* Appendix), certainly would seem to satisfy this need.

In reply to Mr. Kettle, British insurance companies do not make any reductions in premium rates on buildings fitted with lightning conductors, but some Continental companies make very considerable reductions—for instance, in Schleswig-Holstein, reductions are made of from 5 per cent. on slated dwellinghouses to 50 per cent. on churches.

* In March, 1905, the second pyramid of Ghizeh was struck by lightning. This is the first recorded instance of any of the pyramids having been struck.—*Nature*, Vol. 71, 1905.

Mr. Harris's remarks are valuable. His explanation of injury to buildings, &c., as being frequently due to the so-called return shock is no doubt quite correct. The cause of the return shock is, however, hardly to be found in electrostatic attraction. The phenomena are much more likely to be due chiefly to electro-magnetic surges, the return shock being indeed a sort of remote side flash.

Mr. Purcell's account of an earth discharge, unaccompanied by any cloud discharge, is interesting. Three such cases are described by Sir Oliver Lodge,* who regards the damage as due to a surge in, and splash from, some long conductor such as a water or gas pipe, the surge being due to a flash from cloud to earth occurring at some distance away.

In reply to the President's remarks, the figures given had been arrived at by observation, experiment and calculation. Thus, the length of a flash has been frequently observed, and a mile is a very usual length (flashes have been observed of several miles in length, one is said to have been noticed about seven miles long). The voltage is calculated from the length of the flash and the experimental result that it requires about 75,000 volts to break through one inch of air. The frequency is determined from the calculated self-inductance of the path and the estimated capacity of the portion of cloud discharged; and the magnitude of the current which passes, also calculated from these quantities and the voltage, is verified by seeing that it is capable of fusing wires that are known to be fused, and not capable of fusing wires that are known not to be fused.

* Lightning Conductors and Lightning Guards, p. 134, *et seq.*

APPENDIX.

BIBLIOGRAPHY AND REFERENCES.

Anderson (Richard). Lightning Conductors, their History, Nature, and Mode of Application. Third Edition. Large 8vo. London. 1885. [This book contains a bibliography of the subject up to the year of publication.]

Breydel (A.) in Le Cosmos. Paris. 1905.

Lightning Rod Conference, Report of the. Edited by G. J. Symons. 8vo. London. 1882. [Contains a very complete bibliography of the subject up to 1880.]

Lightning Research Committee, Report of the. London. J. R. Inst. Brit. Architects. 1905.

Lodge (Sir Oliver). Lightning Conductors and Lightning Guards. 8vo. London. 1892.

M'Gregor (W.). Protection of Life and Property from Lightning during Thunderstorms. 8vo. Bedford. 1875.

A very complete list of papers dealing with the subject, published between 1880 and 1902 is to be found in the Royal Society Catalogue of Scient fic Papers, and an equally complete list of papers, published since 1902, is contained in the International Catalogue of Scientific Literature.

[29th May, 1908.]

GENERAL MEETING OF CORPORATE MEMBERS.

MR. J. H. MOORE, President, in the Chair.

BUSINESS:—

To alter Bye-laws, Section V., Clause 1, which now reads:—

SECTION V.—*Election of Council and Officers.*

1. At the Ordinary General Meeting in April the Council shall present a list of persons whom they nominate as suitable for the offices of President, Vice-Presidents, Honorary Secretary, and eight other elective Members of Council, for the ensuing year. This list shall have a surplus of at least four names, and shall be the balloting list for the election at the Annual General Meeting in May;

so that Clause 1 shall in future read:—

SECTION V.—*Election of Council and Officers.*

1. At the Ordinary General Meeting next preceding the Annual General Meeting, or at any adjournment thereof, the Council shall present a list of persons whom they nominate as suitable for the offices of President, Vice-Presidents, Honorary Secretary, and eight other elective Members of Council for the ensuing year. This list shall have a surplus of at least four names, and shall be the balloting list for the election at the Annual General Meeting in May.

Resolution proposed by THE PRESIDENT,

Seconded by MR. J. H. HARGRAVE, and carried.

"That Section V., Clause 1, of the Bye-laws be, and the same is hereby, varied by substituting for the words:—

'At the Ordinary General Meeting in April,'

the words—

'At the Ordinary General Meeting next preceding the Annual General Meeting, or at any adjournment thereof.'"

[29th May, 1908.]

ADJOURNED ORDINARY GENERAL MEETING.

Mr. J. H. Moore, President, in the Chair.

The list of persons nominated by the Council as suitable for the offices of President, Vice-Presidents, Honorary Secretary, and Members of Council was presented to the Meeting.

[29th May, 1908.]

ADJOURNED ANNUAL GENERAL MEETING.

MR. J. H. MOORE, President, in the Chair.

The Report of Council for the Session was read to the meeting, as also was the audited statement of accounts for the year 1907.

The following were balloted for and duly elected to be the Officers of the Institution for the Session 1908-9:—

President:
Joseph H. Moore.

Vice-Presidents:
G. M. Ross and P. C. Cowan.

Members of Council:
C. H. Ashworth, J. M. Batchen, F. Bergin, W. Collen, J. H. Hargrave, P. H. M'Carthy, Mark Ruddle, and P. A. H. Shaw.

Hon. Secretary:
Walter E. Lilly.

Hon. Treasurer:
J. H. Ryan.

REPORT OF COUNCIL FOR THE SESSION 1907-8.

THE Council, in presenting their Report on the work accomplished during the Seventy-fourth Session, are pleased to be able to note a continuance of its prosperity. The roll has been added to during the Session by the election of 6 Members, 9 Associate Members, and 1 Associate.

The numbers of Members, &c., at the close of the Session (allowing for deaths and resignations), as contrasted with the previous one, are :—

	Members	Associate Members	Associates
1907-8 -	176	96	45
1905-6 -	171	91	49

The Council note with satisfaction the increase in the roll, and of the usefulness of the Institution to the profession in Ireland.

During the past year the rooms occupied by the Hospitals' Board were renovated and refurnished. The Annual Dinner was held on the 3rd of March at the Shelbourne Hotel, and was the occasion of a representative gathering.

The President has presented two books to the Library. Mr. T. F. Pigot, Past-President, has presented several volumes of drawings of the "Ecole Imperiale des Ponts et Chaussées de Paris," as well as a suitable cabinet in which to preserve same.

The papers contributed by Members during the Session

have not been as numerous as usual. Members will note that the Council will be pleased to consider suitable papers. The attention of the Council having been drawn to an omission to read at the April meeting the List of Proposed Members of Council, it was found necessary, acting upon the advice of Counsel, to recommend a slight alteration in the wording of the Bye-laws, Section V., Clause I., which was duly confirmed at a Special Meeting convened for that purpose.

The Council note, with regret, the decease of the following Members of the Institution:—

William Fawcett Gilcriest, William Spence, and Charles E. Martin.

The following are the Papers read before the Institution during the Session 1907-8:—

November 6th, 1907.—Inaugural Address. By the President.

December 4th, 1907.—"The Quebec Bridge Disaster." By W. E. Lilly, D.Sc., Member.

January 8th, 1908.—"Trinidad Lake Asphalt." By M. W. Foley, Associate Member.

February 5th, 1908.—"Kildare and other Sewerage Works." By F. Bergin, Member.

April 1st, 1908.—"A Short Description of the Works in Connection with the Proposed Additional Storage Reservoir at Roundwood, Co. Wicklow, for the Corporation of Dublin." By J. G. O'Sullivan, Member.

May 6th, 1908.—"The Protection of Engineering Structures from Lightning." By J. T. Jackson, Member.

The following Medals and Premiums were awarded by the Council:—

Mullin's Gold Medal to G. T. M'Caw, Member, for his Paper on "The Progress of Geodesy."

In making the awards, some Papers, of high merit, by Members of the Council were not, in accordance with a resolution of the Council, considered.

The marked thanks of the Council were accorded to—

J. H. Hargrave, Member, for his Paper on "Railway Signalling and Interlocking."

W. E. Lilly, Member, for his Paper on "The Quebec Bridge Disaster."

F. Bergin, Member, for his Paper on "Kildare and other Sewerage."

M. W. Foley, Associate Member, for his Paper on "Trinidad Lake Asphalt."

J. T. Jackson, Member, for his Paper on "The Protection of Engineering Structures from Lightning."

AUDITORS' REPORT FOR 1907.

TRINITY CHAMBERS, 40 & 41 DAME-STREET,

DUBLIN, *January* 17*th*, 1908.

THE COUNCIL OF THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND, 35 DAWSON-STREET, DUBLIN.

GENTLEMEN,

We have audited the Books and Accounts for the year ended 31st December, 1907, and send you annexed hereto Revenue Account and Balance Sheet made up in the usual form.

REVENUE ACCOUNT.

The Revenue Account shows that the Expenditure exceeded the Income by the sum of £272 13s. 11d. This deficiency appears to be the result of extra expenditure in respect of printing, the reason of this being that it was found necessary in the year 1907 to print the Proceedings of the Institution for two years.

You will remember that in the months of March and April last year we made a thorough investigation of the affairs of the Society as regards Entrance Fees and Subscriptions, and, acting under your instructions, circularised the Members and collected all the arrears, so far as possible, and, as we made full reports to you on the subject at the time, there is no need for us to enter into this again, further than to say that, with one exception, all the old arrears

have now been collected. There are still, however, some Subscriptions outstanding for the year 1907, and these are fully set out in the Register of Members.

BALANCE SHEET.

The Assets, exclusive of the Premises, upon which no valuation is placed in your Accounts, amount to £1,565 16s. 2d. These include certain Government Stocks, valued at par, and we think you should consider whether these ought not to be written down to their present market value. We have verified the existence of these Securities in the usual way by a certificate from the Bank of Ireland. Turning to the other side of the Balance Sheet, the Liabilities amount to £273 19s. 7d., leaving a surplus of £1,291 16s. 7d., which is subject to depreciation on the Securities mentioned above, and to the collection of the Subscriptions in arrear.

We are glad to observe that the new Clerk to the Council appears to be doing his work extremely well, the improvement in the Books and Accounts being very marked.

We are,

Yours faithfully,

CRAIG, GARDNER & CO.

THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

BALANCE SHEET, 31*st December*, 1907.

LIABILITIES.		£ s. d.
By Sundry Creditors—		
Printing, &c.	£227 15 9	
Repairs	10 3 9	
Fuel and Light	1 10 0	
Salaries	5 12 0	
Rent	26 5 0	
Hon. Treasurer	2 13 1	
		273 19 7
„ Surplus to the credit of the Institution at 31st December, 1907, exclusive of the value of the Premises, Library, Furniture, and Fittings as per last account,	1,568 14 6	
Deduct—Entrance Fees written off, included in last Account as Arrears	4 4 0	
	£1,564 10 6	
Deduct—Excess of Expenditure over Income for year 1907	272 13 11	1,291 16 7
Total £		1,565 16 2

ASSETS.		£ s. d.
To Subscriptions in arrear	£38 17 0	
Less paid for 1908	13 2 6	25 14 6
„ The Mullin Bequest, £1,172 8s. 3d., 2½ per cent. Consols		1,172 8 3
„ Smith Testimonial Fund, £97 14s. 7d., 3½ per cent. India Stock		97 14 7
„ India 3 per cent. Stock, £135 4s. 6d.		149 15 3
„ Rents receivable		75 10 0
„ Dividends accrued		8 16 7
„ Rates paid in advance		10 0 0
„ Sundry Debtors for Hire of Hall		1 11 6
„ Cash in Bank		24 5 6
„ Premises, 35 Dawson Street, Dublin, held under lease for 200 years from 1892, subject to annual rent of £105 and rates		—
„ Library		—
„ Furniture and Fittings		—
Total, £		1,565 16 2

Dr. *Revenue Account for Year ended 31st December, 1907.* Cr.

INCOME.		£ s. d.	EXPENDITURE.		£ s. d.
By Entrance Fees	£33 12 0		To Printing, Stationery, and Postages	£397 14 1	
,, Subscriptions	354 3 6		,, Framing Photos.	40 0 0	
,, Dividends	35 6 4		,, Sundry Expenses	12 16 5	
,, Rents receivable	110 0 0				450 10 6
,, Hire of Hall and Sundry Receipts	77 2 3		,, Rent payable		105 0 0
		610 4 1	,, Rates, Taxes, Insurance and Repairs		126 14 10
,, Balance being excess of Expenditure over Income for the year 1907, transferred to Balance Sheet		272 13 11	,, Salaries, Fuel and Light		165 8 2
			,, Books and Papers for Library		1 3 6
			,, Expenses—General Meeting, &c.		14 11 0
			,, Accountants' Fee for Audit and Special Work		17 17 0
			,, Subscription refunded		1 13 0
Total, £		882 18 0	Total, £		882 18 0

We have examined the foregoing Revenue Account and Balance Sheet, compared same with the Books and Vouchers of the Institution, and found them to agree.

DUBLIN, *January* 17, 1908.

CRAIG, GARDNER & CO., *Auditors.*

Publications received in exchange for Institution "Transactions."

Engineering.	The Timber Trades Journal.
The Engineer.	The Indian and Eastern Engineer.
The Builder.	Indian Engineering.
The Contract Journal.	Caissier's Magazine.
The Surveyor.	Engineering Record (New York).
Traction and Transmission.	Railway and Tramway World.

Electrical Review.

The Volumes of "Transactions" are exchanged with the following Institutions, &c. :—

American Academy of Arts and Sciences.	Boston.
American Society of Civil Engineers.	New York.
American Society of Mechanical Engineers.	New York.
Canadian Society of Civil Engineers.	Montreal.
Engineers' Club of Philadelphia.	Philadelphia.
Franklin Institute.	Philadelphia
Institution of Civil Engineers.	London.
Institution of Mechanical Engineers.	London.
Institution of Engineers and Shipbuilders in Scotland.	Glasgow.
Junior Institution of Engineers.	London.
Liverpool Engineering Society.	Liverpool.
Midland Institute of Mining, Civil, and Mechanical Engineers.	Barnsley
North of England Institute of Mining and Mechanical Engineers.	Newcastle
Nova Scotian Institute of Science.	Halifax, N. S.
Royal Engineer Institute.	Chatham.
Royal Institute of British Architects.	London.
Royal Scottish Society of Arts.	Edinburgh.
Royal Society of Antiquaries of Ireland.	Dublin.
Smithsonian Institution.	Washington.
Sociedad Cientifica Argentina.	Buenos Ayres.
Society of Arts.	London
Society of Engineers.	London.
Surveyors' Institution.	London.
West of Scotland Iron and Steel Institute.	Glasgow.

LIST OF MEMBERS.

INSTITUTION
OF
CIVIL ENGINEERS OF IRELAND,

Established 1835 (Incorporated by Royal Charter 1877),

35 DAWSON STREET, DUBLIN.

1907-8.

COUNCIL.

President:
JOSEPH H. MOORE.

Vice-Presidents:
G. M. ROSS, | P. C. COWAN.

Other Members:

JOSHUA H. HARGRAVE,
MARK RUDDLE,
R. G. ALLANSON-WINN,
W. COLLEN,
FRANCIS BERGIN,
W. PURCELL O'NEILL,
T. M. BATCHEN,
C. H. ASHWORTH.

Past Presidents:
(*Ex-officio Members of Council*).

BINDON B. STONEY,
WILLIAM H. MILLS,
JOHN A. F. ASPINALL,
JOHN P. GRIFFITH,
SPENCER HARTY,
THOMAS F. PIGOT,
JAMES DILLON,
EDWARD GLOVER,
J. H. RYAN,
ROBERT COCHRANE,
WILLIAM ROSS.

Honorary Secretary:
WALTER ELSWORTHY LILLY.

Honorary Treasurer:
J. H. RYAN.

Bankers:
PROVINCIAL BANK.

HONORARY MEMBERS

(*Hon. M. Inst.C.E.I.*)

ELECTED		
1906	Rt. Hon. John Campbell Earl of Aberdeen, Lord Lieutenant-General and General Governor of Ireland	Vice Regal Lodge, Dublin.
1902	Rt. Hon. William Humble, Earl of Dudley	9 Carlton Gardens, Pall Mall, London, S.W.
1868 M 1882 H.M.	Grubb, Sir Howard, F.R.S., F.R.A.S., &c.	Rockdale, Orwell-road, Rathgar, Dublin.
1897	Cameron, Sir Chas. A., C.B., M.D., F.R.C.S.I. . . .	51 Pembroke-road, Dublin.
1901	Thrift, Professor W. E., F.T.C.D.	Trinity College, Dublin.

MEMBERS

(*M.Inst.C.E.I.*)

1901	Allanson-Winn, Rowland G. A., B.A., Cantab. (*Mem. of Council*)	22 South Frederick-st., Dublin, and Glenbeigh, Killarney.
1904 A.M. 1906 M	Allman, Alfred . .	Harbour Works, Roundstone, Co. Galway.
1892	Alexander, *Professor* Thomas, M.A.I.	39 Trinity College, Dublin.
1898	Allen, Henry, B.E. . . .	Rehoboth House, South Circular-road, Dublin.
1869 F.L.A. 1875 F.L.M.	Apjohn, James Henry, M.A., M. Inst. C.E. (*F.L.M.*)	17 Victoria-street, Westminster, London, S.W.
1880	Armstrong, George Allman .	Timoleague and Courtmacsherry Light Ry., Bandon, Co. Cork.
1877	Aspinall, John Audley Frederick, M. Inst. C.E. (*L.M.*, *Past President*)	Gledhill, Mossley Hill Drive, Sefton Park, Liverpool.
1903	Atock, Thomas, B.A. . .	25 Cabra-road, Dublin.
1880	Backhouse, Marmaduke, M.A.I.	8 & 9 Harcourt-terrace, Dublin.
1902	Bain, Andrew (Major, R.E.) (*L.M.*)	Commissioner of Civil Police, Northern Nigeria, West Africa, Blenheim Club, St. James' Square, S.W.
1896	Barnard, Albert William . .	Coolyhane House, Macroom, Co. Cork.
1896	Barnes, Robert Stephenson .	Tatestown, Navan, Co. Meath.

ELECTED		
1876 A 1879 M	Barnes, John Frederick Evelyn, C.M.G., M. Inst. C.E. (*F.L.M.*)	Chief Engineer, P. W. D., Natal, South Africa.
1874 A 1880 M	Barrington, Edward . .	3514 N. St., N.W., Wash., D.C., U.S.A.
1905	Batchen, Thomas Mackenzie (*Member of Council*)	Westbourne, Temple Gardens Palmerston Park, and Board of Public Works, Dublin.
1865	Beatty, John	India.
1892	Bergin, Francis, B.E. (*Member of Council.*)	Beech Grove, Kildare.
1899	Bergin, John Philip . . .	County Surveyor's Office, 11 Rutland-square, Dublin.
1890	Berry, Joseph . . .	Town Hall, Kingstown, Co. Dublin.
1883	Birch, Edward Robert, . . Assoc. M. Inst. C.E.	Birch Grove, Roscrea, Co. Tipperary.
1905	Boyd, Lucius John . . .	Cherokee Lodge, Lindenhurst, Long Island, New York.
1900	Brett, Henry Charles, B.A., B.E.	19 Wellington-road, Dublin.
1874	Brett, John H. (*L.M.*) . .	Co. Surveyor, Antrim, Belfast.
1895	Buckley, Michael J. . . .	26 Bessboro'-terrace, North Circular-road, Dublin.
1905	Burtchaell, David Edward, B.E.	St. Joseph's Cottage, Howth, Co. Dublin.
1901 A.M. 1906 M	Byrne, John Joseph, . M.I.M.E.	1 Haroldville Terrace, S.C.R., Dublin.
1904	Calwell, Robert Inkerman, B.E.	16 Donegal Square, South, Belfast.
1876 A 1883 M	Chappell, Henry . .	The Grove, Newtownards, Co. Down.
1907	Cheeke, William A.. . .	2 Lower Merrion St., Dublin.
1895	Clarke, Eugene O'Neill, B.E. .	County Surveyor, Leitrim; Carrick-on-Shannon.
1865	Clark, George R. . . .	P. W. D., Darjeeling, India.
1903	Clarke, Henry Wray, M.A. .	Bay View, Larne Harbour, Co. Antrim.
1870 A 1882 M	Cochrane, Robert, LL.D., I.S.O., M.R.I.A., F.S.A., F.R.I.B.A. (*Past President*)	Board of Works, Dublin, and 17 Highfield-road, Rathgar.
1888	Coey, Robert	St. John's, Island Bridge, Dublin.
1890	Coffee, Francis R. . . .	2 Eaton-terrace, Tramore, Co. Waterford.
1902	Collen, William, B.E., M. Inst. C.E. (*Member of Council*)	County Surveyor, Dublin; 70 Upper Leeson-street, Dublin.

ELECTED		
1886	Comber, Patrick Forstall, M.Inst. C.E., F.S.I.	19 Lower Leeson-street, Dublin.
1865	Cooke, Theodore, M.A., M.A.I., LL.D., C.I.E., F.G.S., F.L.S. (*F.L.M.*)	Portswood, Kew Gardens, Surrey.
1906	Cotton, W. F., junr. . .	45 Sir John Rogerson's-quay, Dublin.
1900	Cowan, Peter Chalmers, M. Inst. C.E. (*Member of Council.*)	Local Government Board, Dublin.
1860	Crawford, R., M.E., M. Inst. C.E.	Stonewold, Ballyshannon, Co. Donegal.
1883	Creery, Leslie, B.A.I. . .	Lisnalurg, Shankill, Co. Dublin.
1904 A.M. / 1905 M	Crofts, Freeman Wills .	Engineer's Office, Midland Railway (Northern Counties Committee), Coleraine.
1892	Cusack, Henry Edward . .	M. G. W. Ry. Works, Broadstone, Dublin.
1902	Davis, Charles Henry (*F.L.M*).	25 Broad-street, New York.
1884 A / 1899 M	De Burgh, Ernest Macartney	Union Bank of Australia, Sydney, N.S.W.
1900	Dick, Frederick J., M. Inst. C.E.	Point Loma, Homestead, San Diego, Cal., U.S.A.
1863	Dillon, James, M. Inst. C.E., (*Past President*)	36 Dawson-street, and Stratford House, Glenageary, Co. Dublin.
1862	Dodd, George (*F.L.M.*)	
1908	Downing, Arthur J. .	Old Cabra House, Cabra, Dublin.
1888	Doyle, Patrick (*F.L.M.*), M.R.I.A., F.R.S.	19 Lall Bazar, Calcutta.
1878	Duffin, William Edmund L'Estrange	County Surveyor, Waterford; Larkfield, Waterford.
1907	Eustace, George Needham .	Knockrath, Greystones, Co. Wicklow.
1898	Falion, Bernard N., J.P. .	Netterville Lodge, Toomard, Ballinasloe.
1873 A / 1899 M	Ferguson, William, B.E., M.A., M. Inst. C.E.	Harbour Board, Wellington, New Zealand.
1894	Fletcher, Francis Dudley . .	Shannon Office, Board of Works, Limerick.
1900	Fortescue, Matthew, B.A., B.E.	57 Grosvenor-road, Rathgar, Dublin.
1902 A.M. / 1906 M.	Galbraith, A. de Rohan .	47 London Rd., Southampton.
1903	Gallagher, Stephen Gerald, B.E.	County Surveyor, Wicklow; Wentworth Place, Wicklow.

ELECTED		
1875	Geoghegan, Samuel . .	The Grove, Killiney, Co. Dublin.
1888 A 1893 M	Gilcriest, William Fawcette	Wine-street, Sligo.
1877	Glover, Edward, M.A., B.E., M. Inst. C.E., F.R.I.B.A. (*Past President*)	County Surveyor, Kildare, Courthouse, Naas.
1887 A 1892 M	Going, Shirley Russell (*L.M.*)	17 Nassau-street, Dublin, and 35 Sandycove-road, Kingstown, Co. Dublin.
1895	Gray, George David, B.E. .	36 Edenvale-road, Ranelagh, Co. Dublin.
1903	Griffith, Dudley Perceval . . (*F.L.M.*), M.A., B.A.I.	Imperial Railways of North China; Tongshan, North China.
1871	Griffith, John Purser, M. Inst. C.E. (*Past President*)	Rathmines Castle, Rathmines, Dublin, and Port and Docks Office, East-wall, Dublin.
1886 A 1899 A.M. 1902 M	Hade, W. Patrick .	Dublin-street, Carlow.
1908	Hale, Alexander (*F.L.M.*) .	Howrah, Bengal.
1898	Hargrave, Joshua Harrison, . B.A., B.E. (*Member of Council*)	Great Northern Railway, Amiens-street, Dublin.
1898 A 1902 M	Harris, George Marshall .	Barrow House, Carlow.
1875	Harty, Spencer . . . (*Past President*)	Ranelagh House, Balls-bridge, and Engineer's Office, City Hall, Dublin.
1896	Haycroft, James Isaac, B.E. (*F.L.M.*)	Fontenoy, Ocean-st., Woollahra; Sydney, New Sth. Wales.
1872	Heenan, Robert Henry, M. Inst. C.E.	Harbour Works, Cape Town.
1887	Henderson, Ernest . . .	Canadian Pacific Railway, Smithfalls, Ontario, Canada.
1902	Hickson, George A. E., B.A.I.	25 Denny-street, Tralee.
1895	Hill, William Henry, junr. .	8 York-terrace, Cork.
1897 A 1905 A.M. 1907 M	Higginbotham, Frederick William	9 Lower Sackville Street, Dublin.
1906	Hinde, William Henn . .	2 Lower Merrion-st., Dublin.
1903	Holmes, Sir George, K.C.V.O., C.B.	Chairman, Board of Works Dornden, Booterstown, Co. Dublin.
1906 A.M. 1908 M	Holmes, Henry . . .	Steynton, Courtney Road, Croydon.

ELECTED		
1901	Hope, John Basil, M.I.M.E.	M.G.W.Ry. (Loco. Engineers' Dept.), Broadstone, Dublin; Fernhurst, Orwell Park, Dublin.
1904	Hopkirk, Francis George	Midland Railway (Northern Counties Committee), Belfast.
1897	Hurtzig, Arthur Cameron, M.Inst. C.E.	2 Queen Square-place, Westminster, London, S.W.
1882	Ivatt, Henry Alfred, M. Inst. C.E.	Gt. Northern Ry., Doncaster.
1907	Jackson, James T.	13 Kimmage Road, Harold's Cross, Dublin.
1893	Johnston, George Leopold	Goleen, Co. Cork.
1901	Jolly, James, B.A., B.E.	London United Tramways, Engineers' Dept., High-road, Chiswick, London, W.
1877	Joyce, Arthur Edward	County Surveyor, Westmeath; Ballinagore, Co. Westmeath.
1888	Kaye-Parry, William, M.A., B.E., M. Inst. C.E., F.R.I.B.A.	48 Kildare-street, Dublin, and 6 Charlemont-terrace, Kingstown.
1896	Keating, W. Johnson, B.E.	28 York-road, Rathmines, Dublin.
1907	Kettle, L. J.	27 Northumberland-road, Dublin.
1902	Kirwan, Robert Joseph, B.A., B.E.	Co. Surveyor's Office, Sligo.
1907	Knowles, George H.	65 Upper Tollington Park, London, N.
1906	Lailey, H. G. Nicholson	Barrington House, Trowbridge, Wilts.
1901	Latham, Frank	Municipal Buildings, Penzance.
1883	Latimer, John	5 Clonmore-villas, Tralee.
1898	Leahy, James D.	Newcastle West, Co. Limerick.
1889	Leask, Robert H.	37 College-green, Dublin.
1901	Lilly, Walter Elsworthy, M.A., M.E., D.Sc. (*Hon. Sec.*)	39 Trinity College, Dublin.
1856	Lyons, M. E. (*F.L.M.*)	
1896	Martin, Frank V., B.E. (*L.M.*)	82 North Wall, Dublin.
1898	Maunsell, Richard Edward Lloyd	Mount Vernon, Inchicore, Dublin.
1901	M'Carthy, Patrick Harnett, B.A. B.A.I.	39 Westmoreland-st., Dublin.
1880	M'Donald, Donald	Curran, Larne Harbour, Co. Antrim.

ELECTED		
1895 A 1905 A.M. 1908 M	McCaw, George T., M.A., B.A.I., F.S.I.	Taghnevan, Lurgan.
1904	MacFarlane, Robert Melbourne (*F.L.M.*), L.C.E., Bombay University	Alibag, Ratnagiri and Kolaba District, Bombay Presidency, India.
1882 A 1892 M	M'Mullen, James F. . .	30 South Mall, Cork.
1882	Metge, Peter Ponsonby . .	Killinure, Athlone.
1905	Miles, George Francis . .	St. Augustine, Florida, U.S.A.
1877	Mills, William Hemingway, M. Inst. C.E. (*Past President*) .	Nurney, Glenageary, and Great Northern Railway, Dublin.
1894 A 1899 A.M. 1908 M	Moore, George Tighe .	1 and 2 Foster-place, Dublin.
1869 A 1874 M	Moore, Joseph Henry, M.A.I., T.C.D. (*President*)	5 Brookfield-terrace, Donnybrook.
1900	Moore, William P. . . .	11 Herbert-road, Sandymount, and Port and Docks Office, East Wall Dublin.
1879 A 1882 M	Morony, Henry Vereker Lloyd, B.E., Assoc. M. Inst. C.E.	Harbour Commissioners' Office, Limerick.
1866	Morris, Thomas B., M. Inst. C.E.	Messrs. King, King & Co., Bombay.
1888	Morris, William Henry . .	Londonderry and Lough Swilly Ry., Engineer's Office, Londonderry.
1881	Moynan, John Ousley, M.A. .	Co. Surveyor, North Tipperary, Nenagh.
1888	Moynan, Joseph, B.E., Assoc. M. Inst. C.E.	Dundas Shire, Hamilton, Victoria, Australia.
1883	Mulvany, Christopher, M.A., B.E., M. Inst. C.E. .	Garrow, Athlone.
1882	Myles, Thomas Joseph, B.A., M. Inst. C.E.	Engineer's House, M.G.W. Ry., Athlone.
1903	O'Brien, Edward S., B.E. .	Westown House, Wexford.
1896	O'Neill, William Purcell . . (*Member of Council*)	Highfield, N.C. Road, Dublin, and Engineer's Office, M. G. W. Railway.
1887 A 1899 M	Ormsby, Charles Croasdaile	District Engineer's Office, M. G. W. Ry., Galway.
1903	Ormsby, Michael T. Morley .	95 Abbeville-road, Clapham, London, S.W.

ELECTED		
1869 A 1876 M	Ormsby, Robert Daly	St. Ann's, Killiney, Co. Dublin.
1892 A 1898 M	O'Sullivan, John G., Assoc. M. Inst. C.E.	7 Breffni Terrace, Sandycove, Co. Dublin.
1901 A.M. 1903 M.	O'Sullivan, Patrick F.	Tolka View, Richmond-road, Fairview, Dublin.
1898	Parshall, Horace F.	Salisbury House, London Wall, London, E.C.
1891 A 1891 M	Payne, Sinclair William	Upton House, Upton, Co. Cork.
1895	Perrott, William George, B.A., B.E., Assoc. M. Inst. C.E.	Gracefield House, Blackrock, Co. Dublin.
1874	Pigot, Thomas F. (*Past President*)	14 Fitzwilliam-place, Dublin.
1903	Pilkington, Thomas Henry	Glenard, Clare Castle.
1897	Porter, Samuel	13 Tollemache-road, Birkenhead.
1896	Price, James, B.E., M. Inst. C.E.	Engineer, Harbour Commissioners, Cork.
1883 A. 1901 M.	Purcell, Marmaduke F.	Victoria Lodge, Donnybrook, Co. Dublin.
1908	Rhind, Robert H.	12 Spencer Villas, Adelaide Rd., Kingstown, Co. Dublin.
1897 A. 1906 A.M. 1906 M.	Richardson, Thomas H.	c/o Grindley & Co., Calcutta.
1874 A 1893 M	Ross, George Murray, M.A., B.E. (*Member of Council*);	48 Kildare-street, Dublin.
1884	Ross, William, B.A.I., T.C.D. (*Past President*)	66 North Wall, Dublin, and Summerfield, Dalkey.
1907	Ross, William, B.A., B.A.I., T.C.D.	
1893	Rowe, James Thomas	25 St. Andrew's-terrace, North Circular-road, Dublin.
1896	Ruddle, Mark, M.I.E.E. (*Member of Council*)	7 Lansdowne-terrace, Shelbourne-road, Dublin.
1902	Ryan, Hardinge Stanley, B.A.I.	Summerhill Cottage, Nenagh.
1896	Ryan, John Henry, M.A., M. Inst. C.E.; Member of Council, Inst. C.E. (*Past President and Hon. Treas.*)	22 Nassau-street, Dublin, and 25 Herbert-place, Dublin.
1882 A 1887 M	Shannon, Samuel James, B.E.	Claremont, Meath Rd., Bray, Co. Wicklow.
1881	Shaw, Prosser Austin Haynes, L.C.E., T.C.D.	21 Clarinda-park, Kingstown, and St. James' Gate Brewery, Dublin.

ELECTED		
1906	Sheardown, Percy S.	Danum, Pembroke Park, Co. Dublin.
1896	Smith, John Chaloner	Engineer's Office, Board of Works, Dublin.
1861	Smyth, John, M.A., F.C.S.	Milltown, near Banbridge.
1881 A. 1894 M.	Smyth, Richard O'Brien	2 Kenilworth-square, Rathgar and Local Government Board, Dublin.
1882	Stewart, Abraham M'Causland, B.E.	Victoria Chambers, Strand, Derry.
1904	Stewart, Percy Herbert	St. James's Gate Brewery, Dublin.
1902	Stirling, J. A. Maxwell (*F.L.M.*), A.M.I.M.E., M.S.A., M. Arch. Assocn.	Harbour Works, Madras Port Trust, Madras.
1857	Stoney, Bindon Blood, F.R.S., LL.D., M.R.I.A., M. Inst. C.E. (*L.M.*), *Past President.*	14 Elgin-road, Dublin.
1868	Stoney, Edward Waller, M.E., M. Inst. C.E. (*F.L.M.*)	
1873	Stoney, Robert Vesey (*L.M.*)	Rosturk Castle, Co. Mayo.
1872	Stoney, Thomas Butler (*F.L.M.*)	Oakfield, Raphoe, Co. Donegal.
1891	Sutter, Charles H. N.	12 and 13 William-street, Dublin.
1882	Thomson, Frank William, B.E.	Ceylon.
1901	Towle, John William	55 Lots-road, Chelsea, London, S.W.
1903 A.M. 1906 M.	Tomlinson, Thomas, B.A.I., T.C.D., M.I.E.E.	Westmoreland-street, Dublin.
1860	Tuthill, Robert Reeves	
1893	Vereker, Henry Robert, F.S.I.	Ardvillagh, Claremorris.
1903	Wakeman, William James Perrin	117 Cavehill-road, Belfast, and Gt. Northern Railway (I.), Belfast.
1865	Waller, George Arthur, M.A. (*L.M.*)	Tasmania.
1862	Walpole, Thomas	Windsor Lodge, Seafield-avenue, Monkstown, County Dublin.
1875	White, Henry Vincent	County Surveyor, Queen's Co., Maryborough.
1874	Willson, Frederick Richard Thomas, B.E.	Lake View, Kilrea, Co. Londonderry.

ELECTED		
1897	Wilson, John George, B.E. .	Ivy Holme, Ripley, Surrey.
1876 A 1880 M	Wise, Berkeley Deane, M.Inst. C.E.	Silverstream House, Greenisland, and Midland Railway (Northern Counties Committee), Belfast.
1871	Wright, John Arthur (*F.L.M.*)	Cadiz Water Works, Sto. Cristo 4, Cadiz.

ASSOCIATE MEMBERS.

(*Assoc. M. Inst. C.E.I.*)

1897 A 1899 A.M.	Acton, John Henry, B.E.	Civil Eng. Staff, East Indian Railway, Calcutta.
1905	Anderson, Edgar, B.E. .	Glenavon, Merrion-road, Dublin.
1906	Ashe, A. Victor . .	Ballyduff House, Tullamore, King's Co.
1895 A 1899 A.M.	Ashworth, Charles Herbert, F.R.I.B.A., F.R.I.A.I. (*Member of Council*)	12 and 13 William-street, Dublin.
1879 A 1899 A.M.	Barnes, Robert Samuel Wemyss, Assoc. M. Inst. C.E.	Listerlin, 31 Corfton-road, Ealing, London, W.
1900	Barnes, Robert Stephenson, junr.	Tatestown, Navan, Co. Meath
1888 A 1899 A.M.	Barry, William Fitzgerald, Assoc. M. Inst. C.E.	County Surveyor, Monaghan; Town View, Monaghan.
1905	Bates, John . .	Castlerea, Co. Roscommon.
1905	Biggs, Thomas J. . .	Corkbeg Terrace, Whitegate, Co. Cork.
1900	Blake, John J. . .	Ballyglunin Park, Co. Galway.
1903	Blanchard, James Francis	c/o Superintending Engineer, Office of Quebec Canals, Montreal.
1906	Bomford, Charles F. .	Oakley Park, Kells, Co. Meath.
1902	Browne, Henry . .	1 Cumberland-terrace, Birr.
1902	Butler, Rudolph M., F.R.I.B.A.	12 Dawson-street, Dublin.
1903	Bretland, Arthur White .	10 Appian Way, Leeson Park, Dublin.
1907	Burke, Arthur Ulick .	3 Fortwilliam Terrace, Antrim Road, Belfast.
1902	Clancy, Charles . .	Glencar, Clontarf.

ELECTED		
1907	Clarke, William . .	The Poplars, Cyprus Park, Bloomfield, Belfast.
1906	Clegg, W. H. . .	127 Albion Street, Leeds.
1901	Colaco, Alinsio Leonard (*F.L.A.M.*), L.C.E., Bombay University	9 Hornby-road, Fort, Bombay.
1907	Conyngham, Ernest K. .	Sandon, Ballsbridge, Co. Dublin.
1906	Cooke, J. E. . . .	48 Wray Crescent, Tollington Park, London, N.
1901	Crawcour, Charles E. S.	Glen View, Howth, Co. Dublin.
1896 A 1904 A.M.	Cuttriss, Alfred W. M. .	Lound Road, Kendal.
1889 A. 1907 A.M.	Deane, Louis E. H. .	Local Government Board.
1896 A 1899 A.M.	Delaney, James, B.E. .	County Surveyor, King's Co.; Tullamore.
1898 A 1899 A.M.	Dillon, J. T. Trevor, B.A., B.E.	c/o Grindley & Co., Calcutta.
1900	Douglas, Charles K. .	Foxbrook, Moyvalley.
1908	Down, James N. . .	Glanmire Lodge, Glanmire, Cork.
1908	Draper, Francis E. .	Mitchelstown, Co. Cork.
1908	Dunn, Cecil J. . .	3 Weston Terrace, N.C.R., Dublin.
1896 A 1899 A.M.	Evans, Richard . .	53 South Mall, Cork.
1908	Farnham, William A. .	Council Offices, Sidcup.
1896 A 1899 A.M.	Fitzgerald, Cecil Henry (*F.L.A.M.*)	Assistant City Engineer, Georgetown, Demerara, British Guiana.
1903	Fleming, John Joseph .	44 Lady-lane, Waterford.
1907	Foley, Michael W. . .	County Surveyor's Office, Tralee, Co. Kerry.
1895 A 1899 A.M.	Forsyth, Thomas . .	1 Eaton Square, Terenure Park, Dublin.
1887 A 1899 A.M.	Gaffney, Francis Sebastian, Assoc. M. Inst. C.E.	Colonial Engineer's Office, Singapore, S.S.
1903	Galbraith, Frederick Victor (*F.L.A.M.*)	Costa Rica Railway, San Jose, Central America.
1907	Galwey, J. E. de Burgh .	3 Lansdowne Gardens, Dublin.
1903	Grant, Lawford Stanley Foster, A. M. I. E. E., M.S.A.	G.P.O., Box 2500, Montreal, Canada.

ELECTED		
1905	Greene, Rawdon . .	St. Helen's, Bray, Co. Wicklow.
1904	Griffith, John William, M.A., B.A.I. . .	Greenane, Temple-road, Rathmines, Dublin.
1908	Hall, Richard H. C. .	Dublin Rd., Naas, Co. Kildare.
1898 A 1902 A.M.	Hargrave, William Harrison	68 Grosvenor-square, Rathmines.
1896 A 1901 A.M.	Harris, Herbert T. . .	30 Parliament-street, Dublin.
1902	Hughes, Richard Lloyd .	71 Lansdowne-road, Dublin.
1900	Hurley, Hugh Stanislaus .	Park House, Athy.
1902	Inglis, John Joseph .	18 Nassau-street, Dublin.
1906	James, William Henry .	Marine Lodge, Dalkey, Co. Dublin.
1904	Jephson, George Hastings	Court House, Waterford.
1903	Joynt, George Lawrence	Town Surveyor's Office, Ballina, Co. Mayo.
1906	Kelly, E. A. Redfern .	Malone Park, Belfast.
1908	Kelly, George J. S. P. .	2 Elim Terrace, Belmount, Belfast.
1902	Kerr, Henry Forrest, B.E.	37 Clarinda-park, West, Kingstown, Co. Dublin.
1905	Kirk, John Wright .	1 Pimlico Road, London, S.W.
1902	Krishna, Nil, Sen. . . (*F.L.A.M.*)	227/33 Upper Circular-road, Shambazar, Calcutta.
1901	Leask, Henry Norman .	35 Caithness Drive, Egremont, Cheshire.
1906	Macnab, E. S. Macgregor	2 Corrig-avenue, Kingstown, Co. Dublin.
1902	Magill, Joseph Ponsonby .	Beaufort, Co. Kerry.
1907	Marr, J. Heppell .	Smithstown House, Castlecomer, Co. Kilkenny.
1903	Maxwell, Alexander .	Harbour Works, Liscanor, Co. Clare.
1905	Moore, James, A. M. Inst. C.E.	19 Nassau Street, Dublin.
1908	Morris, Patrick R. .	Newrath House, Waterford.
1908	Murphy, Jeremiah T. .	17 Main-street, Naas, Co. Kildare.
1905	Murphy, Richard Charles .	296 Jones Avenue, Toronto, Canada.
1905	Murphy, William Elliott	R.E. Offices, Engineers' Park, Curragh Camp, Co. Kildare.
1906	M'Allan, M. Hunter, . (*F.L.A.M.*)	Municipal Waterworks, Calcutta.

ELECTED		
1904	M'Alery, Joseph Richard Pike	Engineer's Offices, Argentine Great Western Railway, Mendoza, Arg. Republic.
1903	M'Candliss, John C. .	10 Downshire-road, Newry.
1890 A 1899 A.M.	MacGarvey, Howard .	Lombard Works, 62 Townsend Street, Dublin.
1903	M'Grath, Joseph P. .	100 Leinster-road, Rathmines, Dublin.
1903	Nicolls, George A. .	c/o Congested Districts Board, Dublin.
1901	O'Connell, James . .	Altmuish Cottage, Kilmainham Wood, Co. Meath.
1903	O'Neill, Thomas J. . .	19 Crumlin-road, Belfast.
1902	Pansing, John . . .	Church-hill, Wicklow.
1907	Quigley, James . .	County Surveyor, Navan, Co. Meath.
1907	Quinn, Denis J.	Gordon House, Newbridge, Co. Kildare.
1887 A 1902 A.M.	Rochford, John . .	4 Clarinda-park, West, Kingstown, Co. Dublin.
1904	Rockett, Joseph Alexander	10 Sunridge-terrace, S.C.R., Kilmainham, Dublin.
1903	Roe, George Deane . .	Roebuck Lodge, Dundrum.
1908	Ryan, John A. . .	33 Catherine St., Waterford.
1901	Sheehy, Bryan Edward Fitzgerald.	57 George-street, Limerick.
1797	Smith, John . .	Kellystown, Clonsilla, Co. Dublin.
1904	Sparrow, William Warburton Knox (*F.L.A.M.*)	Asst. Engineer, Cape Government Railways, Dist. Engineer's Office, Queenstown, Cape Colony.
1893 A 1899 A.M.	Spence, Arthur William .	Lithgow, Oakley-road, Ranelagh, Co. Dublin.
1906	Stevens, George John .	Chief Engineer, United Havana Railways, Aspertado 450, Havana, Cuba.
1902	Stewart, Pakenham Thomas, B.A., B.E.	Cooleen, Osborne Park, Belfast.
1906	Stones, James . .	Sedgefield, Co. Durham.
1902	Taylor, Henry Thomas .	11 Newton-road, Hoylake, Cheshire.
1906	Townsend, Francis Gerald	Main Street, Ballyshannon, Co. Donegal.

ELECTED		
1890 A 1899 A.M.	Warren, George Gates	Jamaica
1903	Wise, James Berkeley	Cork, Bandon, and South Coast Railway, Bandon, Co. Cork.
1905	Wilmot, John Charles, M.R.I.A.I.	3 Lr. Merrion Street, Dublin.
1905	Wilson, William Cranwill	5 S. James'-terrace, Malahide, Co. Dublin.
1905	Woods, Ernest Lucius	Ailsa Terrace, Seacliff-road, Bangor, Co. Down.

ASSOCIATES.

(*Assoc. Inst. C.E.I.*)

1884	Anderson, William, J.P.	9 Upper Sackville-street, and Glenavon, Merrion-road, Dublin.
1896	Allen, William Henry	The Terrace, Ennis, Co. Clare.
1896	Benson, William Arthur Sanders	144 Dharamtola Street, Calcutta.
1895	Bingham, Charles H.	Messrs. Tedcastle, M'Cormick, & Co., Dublin.
1898	Bolton, Samuel H. (*F.L.A.*)	19 Upper Merrion-street, Dublin.
*1905	Broderick, J. W.	18 Charleston-avenue, Rathmines, Co. Dublin.
*1902	Browne, George	46 Rathgar-avenue, Co. Dublin.
*1902	Callaghan, Alfred J., LL.D.	11 Northumberland-road, Dublin.
*1901	Clayton, Henry F.	6 Fleet-street, Dublin.
*1903	Cornwall, Alfred M.	Thomasfort, Ballygar, Co. Roscommon.
1896	Espinasse, James	c/o Standard Bank of South Africa, Cape Town.
1883	Evans, James	22 St. Peter's-road, Phibsborough, Dublin.
1874	Falkiner, Nathaniel L.	Port Chalmers, New Zealand.
1881	Fleming, Henry	Chicago, U.S.A.

* Marked thus are Non-Corporate Associates.

ELECTED		
1885	Gill, Robert Paul . . .	30 Castle-street, Nenagh.
1895	Gilcriest, John Fawcette . .	Wine-street, Sligo.
*1901	Gordon, C. W. . . .	53 Northumberland-road, Dublin.
1879	Gray, William Armroyde . .	New York.
1896	Hewitt, William Tyrrell O. B., F.R.G.S. .	West Indian Club, Howard Hotel, Norfolk-st., London, S.W.
1896	Kelly, Cecil Fletcher . .	Johnstown House, Athlone.
1895	Lamon, Thomas W. . .	Newtownards, Co. Down.
1885	Maguire, William Robert . .	Tower Hill, Dalkey, and 10 Dawson-street, Dublin.
1888	Martin, John E., B.A., T.C.D. (*L.A.*) .	82 North Wall, Dublin.
*1903	M'Ardle, Arthur Andrew .	Talbot Villa, Sydenham, Belfast.
1898	M'Cann, Walter . . .	Town Surveyor, Drogheda, Co. Louth.
1893	M'Kenzie, Colin Douglas . .	Burton Ville, Southampton-street, Farnboro', Hants.
*1903	Mooney, Frederick Morgan .	118 Pembroke-road, Dublin.
1898	Morris, Ernest Horatio . .	Zakle, Eglington Rd., Donnybrook, Dublin.
1892	Mulville, Michael Walsh . .	Court-road, Listowel, Kerry.
1881	Murphy, William M. . .	Dartry, Rathmines, Dublin.
*1900	Nolan, Edward P. . . .	The Quoile, Downpatrick.
1897	O'Kelly, W. H. . . .	Sion House, Glenageary, Co. Dublin.
1893	Owen, Charles Austin . .	29 Molesworth-street, Dublin.
1888	Power, James Talbot, D.L. (*L.A.*)	Leopardstown Park, Co. Dublin.
*1903	Quirk, Charles James . .	Prospect, Milltown, Co. Dublin.
1895	Reinhardt, John . . .	The Cottage, Monkstown, Co. Dublin.

* Marked thus are Non-Corporate Associates.

ELECTED		
*1904	Rutherford, William Reid	Main-street, Ballybay, Co. Monaghan.
*1905	Shaw, Samuel	16 Ulverton Road, Dalkey, Co. Dublin.
*1908	Sparrow, Frank E.	L. G. B., Dublin.
1892	Stuart, William Henry	Bandora, Ball's-bridge, Dublin.
*1901	Tatlow, Joseph	M. G. W. Ry., Broadstone, Dublin.
1887	Tresilian, Richard S.	9 Sackville-street Upper, and Cumnor, Eglinton-road, Donnybrook, Co. Dublin.
1887	Watson, Charles W.	Hollywood House, Princes-st., Melbourne, Australia.
1867	Woodward, Richard Caleb	Brisbane, Queensland.
1881	Worthington, Robert	40 Dame-street, Dublin.

* Marked thus are Non-Corporate Associates.

NOTE—*L.M., Life Member; F.L.M., Foreign Life Member; L.A.M., Life Associate Member; F.L.A.M., Foreign Life Associate Member; L.A., Life Associate; F.L.A., Foreign Life Associate.*

STUDENTS.

Crossley, H. J.	3 Victoria Place, Athlone.
McClelland, W. A.	Engineer's Office, Broadstone Station, Dublin.
Manico, W. A.	St. Elmo, Sutton, Co. Dublin.
Murray, L. de W.	Chief Engineer's Office, Broadstone, Dublin
O'Neill, Hugh J.	Engineer's Office, Broadstone, Dublin
Preece, E. J.	129 South Circular Road, Dublin.
Ryan, W. F.	7 Chapel Street, Castlebar, Co. Mayo.
Seigne, Richard Barter	Estate Office, Kilkenny.

Printed by JOHN FALCONER, 53 Upper Sackville-street, Dublin.

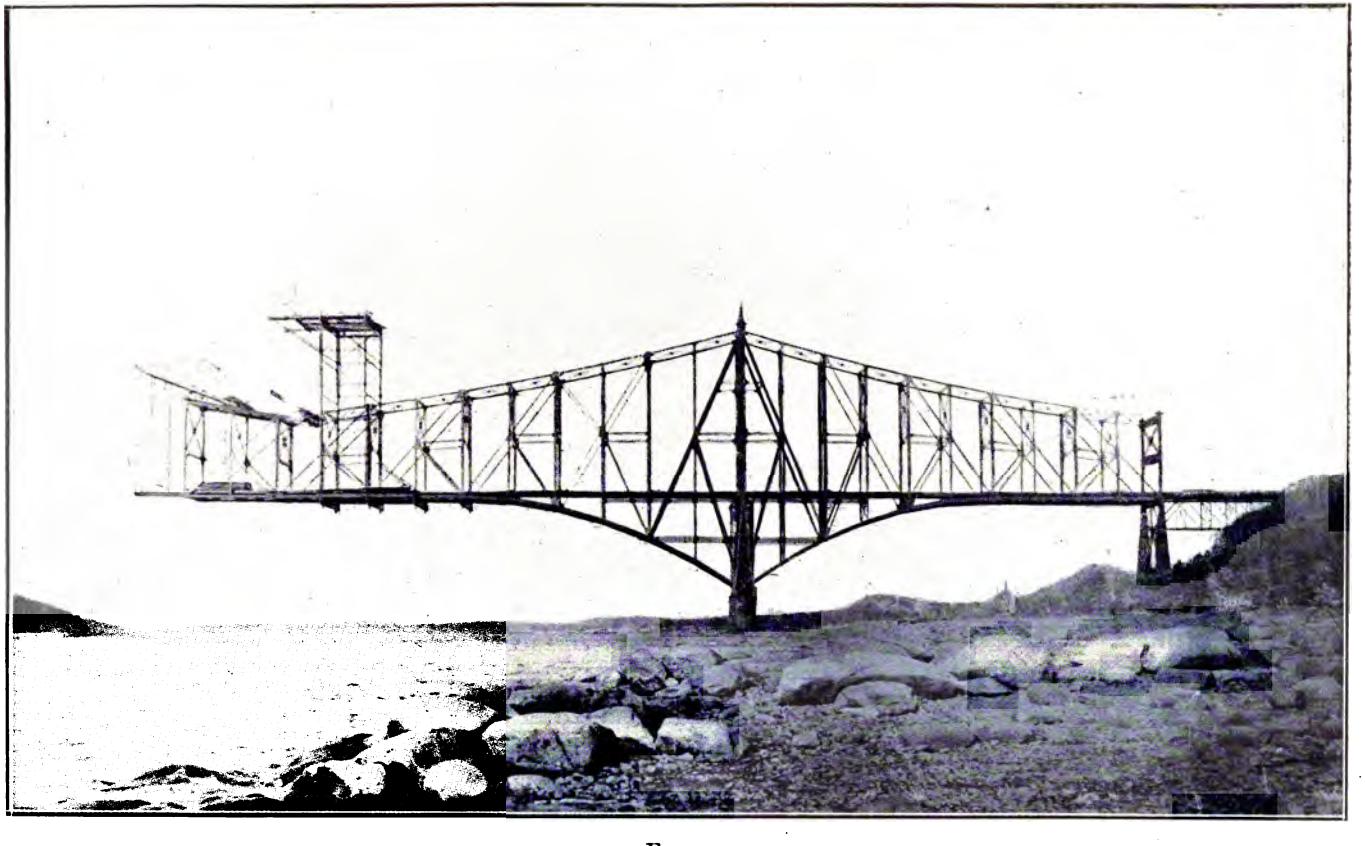

FIG. 1.

FIG. 2

FIG. 3.

FIG. 4.

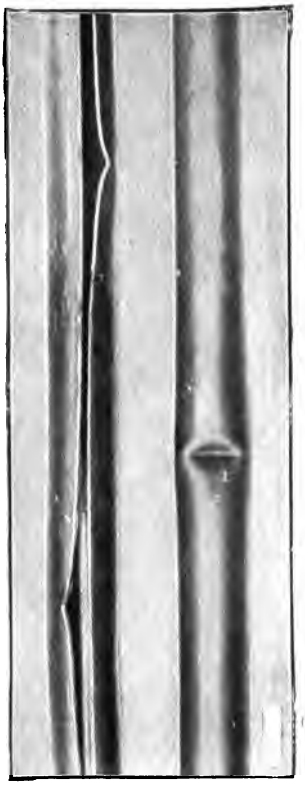

FIG 5.

FIG. 6.

FIG. 7.

FIG. 8.

FIG. 9.

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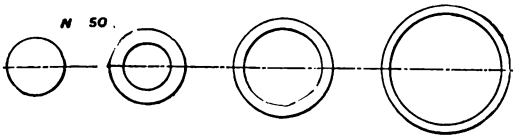
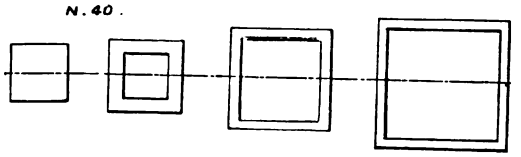


FIG. 5A.



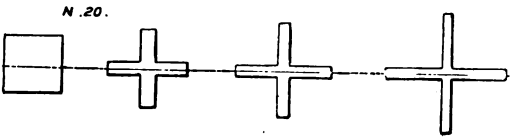
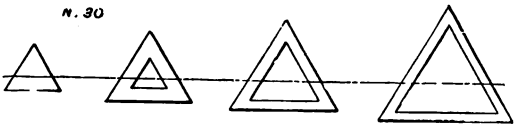


FIG. 5B.



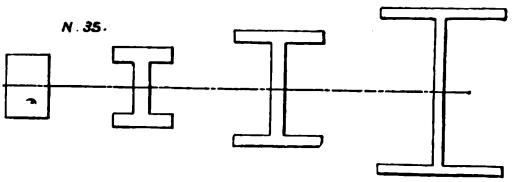


FIG. 5C.

FIG. 10.

FIG. 11.

FIG. 12.

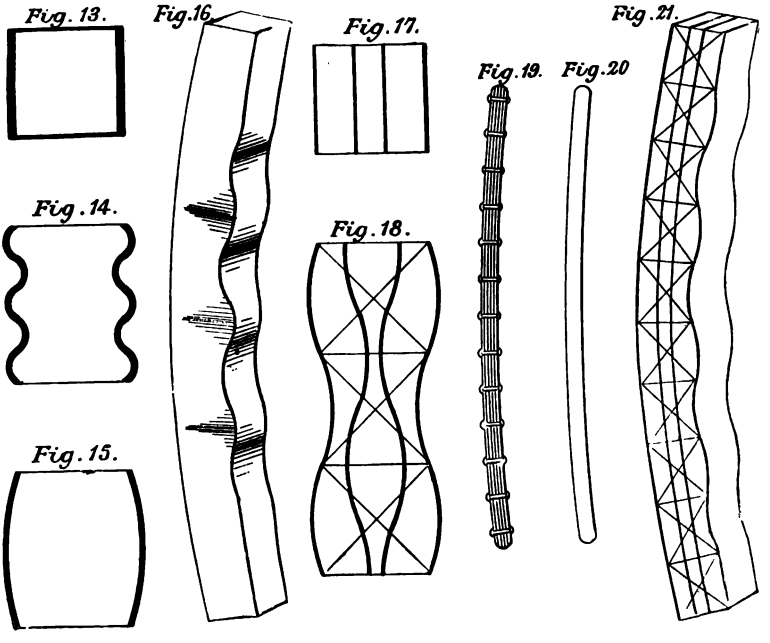


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FIG. 4.

FIG 5.

FIG. 6.

FIG. 7.

FIG. 8.

FIG. 9.

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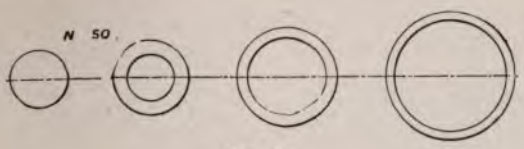

FIG. 5A.

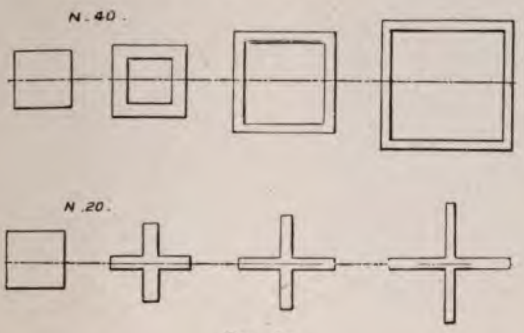

FIG. 5B.

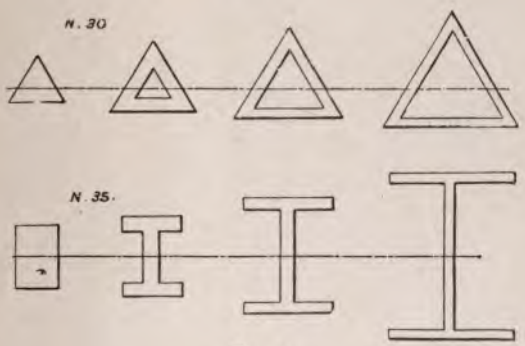

FIG. 5C.

FIG. 10.

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TRINIDAD LAKE ASPHALT.

FIG. 2.

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FIG. 3.

TRINIDAD LAKE ASPHALT.

FIG. 2.

Fig. 5.

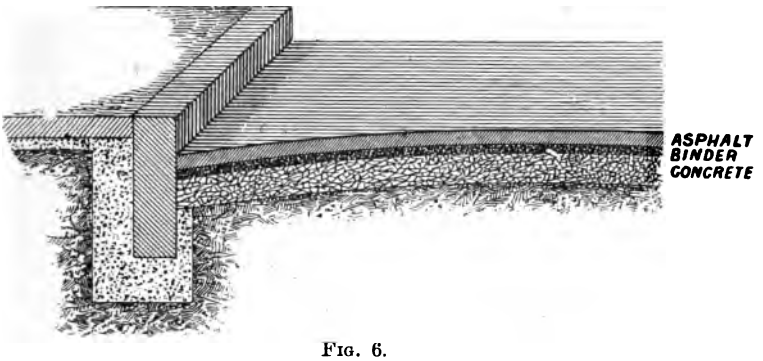


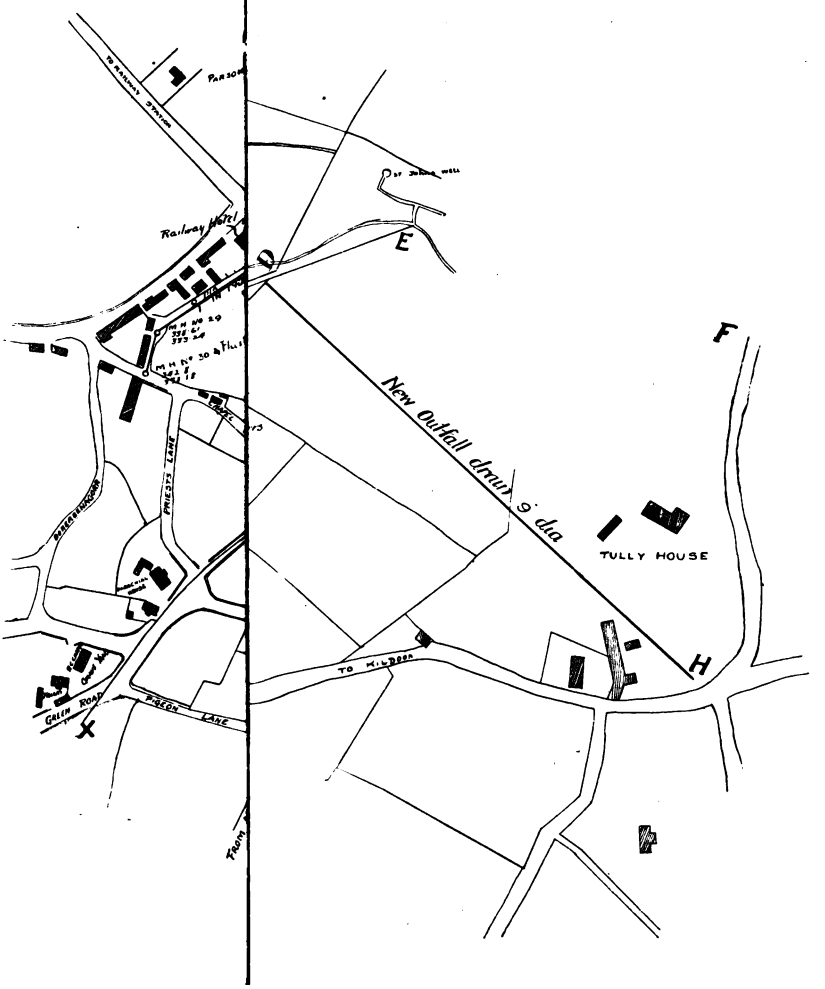
FIG. 6.

KILDARE SEWERAGE

PLAN

SCALE

200 FEET TO 1 INCH



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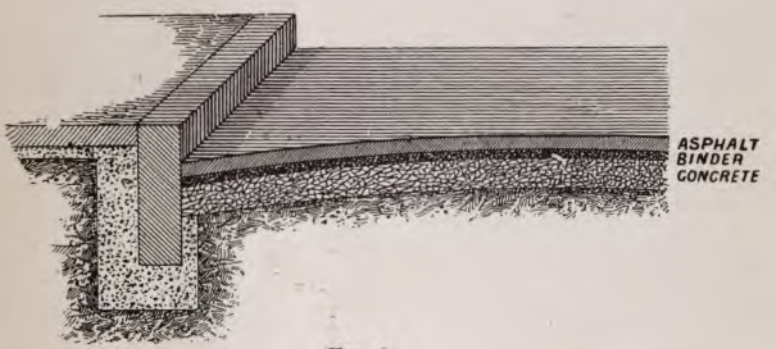

FIG. 6.

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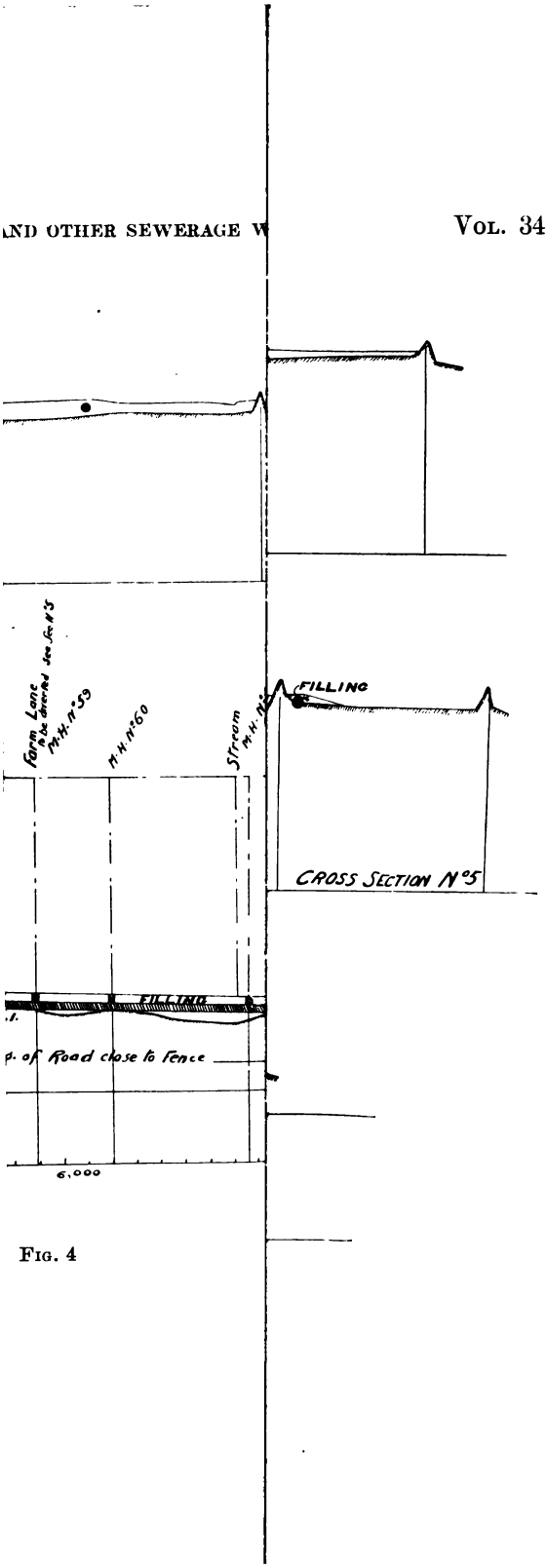
Farm Lane
M.H. N°59
M.H. N°60
Stream
FILLING
CROSS SECTION N°5
of Road close to Fence
6,000

FIG. 4

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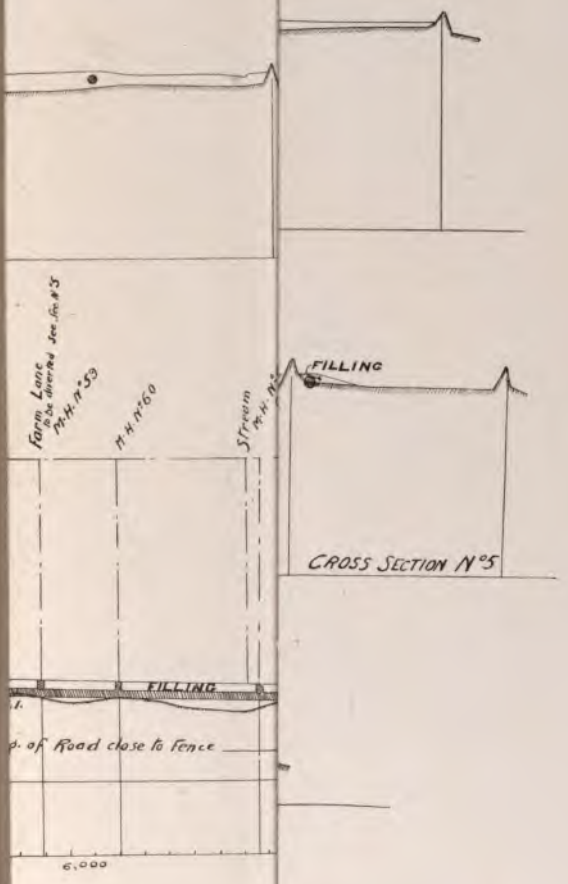
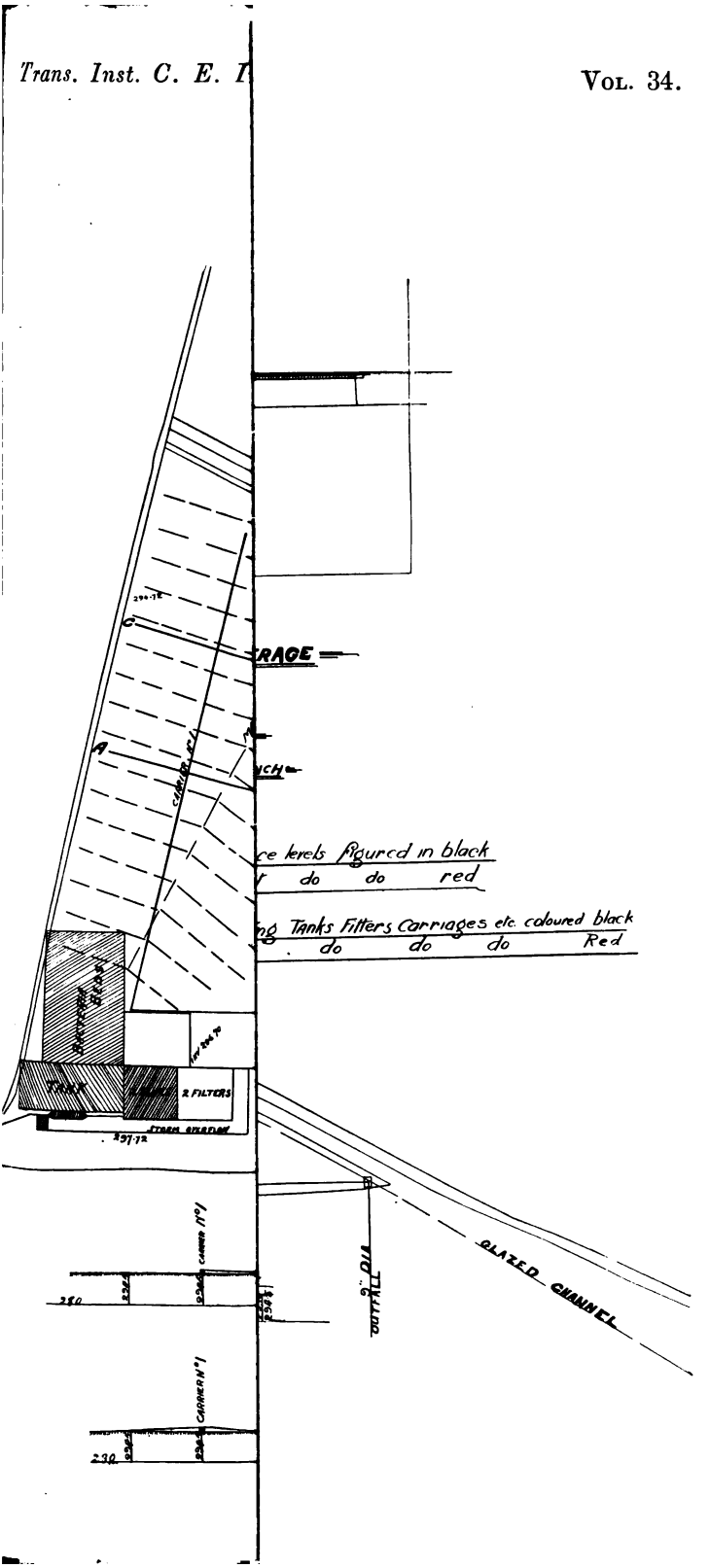

Farm Lane
to be diverted See fig. N°5
M.H. N°53
M.H. N°60
Stream
M.H. N°
FILLING
CROSS SECTION N°5
FILLING
of Road close to Fence
6.000

FIG. 4


RAGE
ce levels figured in black
do do red
ng Tanks Filters Carriages etc. coloured black
do do do Red
2 FILTERS
STORM OVERFLOW
297·72
CARRIER No 1
CARRIER No 1
GLAZED CHANNEL
OUTFALL
230

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GROUNGHMORE.
BALLINASTOE.
RESERVOIR.
KNOCKTHEWER.
TO BRAY
TO DELGANY

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GHMORE.
BALLINASTOE.
ROUN
VOIR.
KNOCITHEWER.
TO BRAY
VERTRY RIVER
TO DELGANY

W.
OVERFLOW SHAFT
To Newtown
From Roundwood

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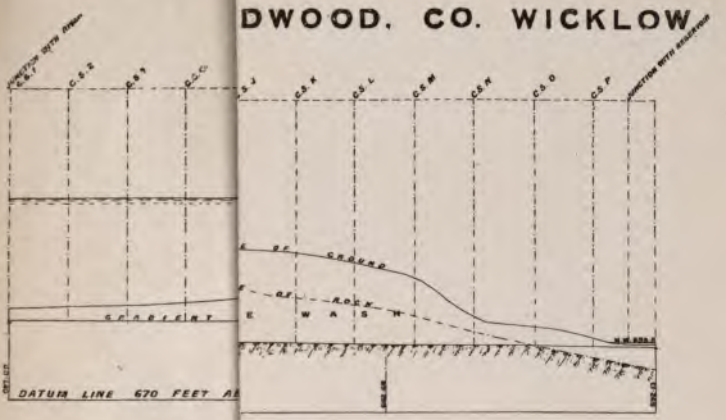
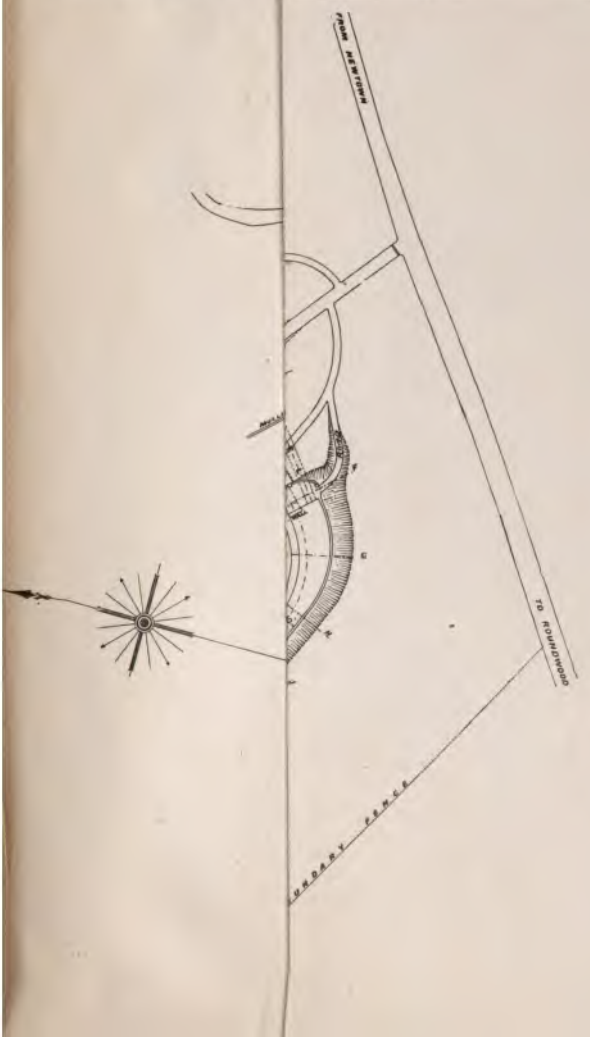
DWOOD. CO. WICKLOW.





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